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THE UNIVERSITY OF ALBERTA

THE GEOLOGY OF THE N81 Zn-Pb DEPOSIT, PINE POINT, N.W.T.

by

SANDRA JEAN FOSTER

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF GEOLOGY

EDMONTON, ALBERTA

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled The Geology of the N81 Zn-Pb Deposit, Pine Point, N.W.T. submitted by Sandra Jean Foster in partial fulfilment of the requirements for the degree of Master of Science.

Supervisor

RABaum

J F Lerbekmo

R E Folinsbee

Date: April 18 1989

DEDICATION

I lovingly dedicate this thesis to my parents Eleanor and Earle Foster, in appreciation for their continued support, both moral and financial. Their assistance was invaluable, and enabled me to acquire both my university degrees.

Also worthy of acknowledgement is Mrs. Eva Cleghorn, my first science teacher, who taught me the basic principles and importance of scientific research and report writing.

ABSTRACT

The N81 orebody at Pine Point, N.W.T., on the shore of Great Slave Lake contained approximately 3Mt of ore grading 12% Zn and 7% Pb.

The base metal deposits of the Pine Point district are of the Mississippi Valley-type and are hosted by a Middle Devonian "barrier complex", which developed along the northern margin of the Elk Point evaporitic basin.

N81 was a typical "prismatic-style" deposit which consisted of two penetrative lobes of vertical dissolution, rooted in a paleokarst horizon, which stoped upward into the younger platform carbonates.

N81 was a deep deposit by Pine Point standards, being covered by 20m of overburden and up to 20m of caprock. This was in contrast to subcropping orebodies located farther east along the barrier. Due to its stratigraphic position, below subcrop, N81 provided a unique opportunity to study a complete prismatic deposit, unaffected by glacial erosion.

An hypothesis modelling the origin and controls of the N81 deposits is developed via descriptive documentation of open-pit exposures, drill-cores, representative polished thin-sections and investigation of the stable isotope compositions of the constituent minerals. The results of these studies indicated that the N81 ores could have formed at the site of a halite/sulphate evaporite diapir which was slowly invaded by metal-bearing formation waters. As the salt dissolved and the waters invaded the diapir, sulphate-reducing bacteria attacked resident hydrocarbons and evaporitic sulphates. As the bacteria consumed local pockets of organic materials and attacked and consumed the sulphates, they released CO_2 and generated H_2S and HS^-. These would then pervade the reservoir and gradually react with the metal ions in the formation waters, thus precipitating sulphides.

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Dr. R.C. Armstrong and K.M. Carter recognized the unique learning opportunity presented by N81 and were instrumental in getting this project underway.

Pine Point Mines Ltd. provided access to the N81 mine and drill core as well as shipping samples and preparing the polished thin-sections.

The assistance of Dr. A. Changkakoti was invaluable in the stable isotope study. Dr. J. Gray and Dr. H.R. Krouse generously permitted use of their laboratory facilities.

Felipe Ortigoza-Cruz kindly assisted in the sulphur isotope analyses.

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CHAPTER 1

INTRODUCTION

1.1 General Setting

The Pine Point mining district is located approximately 800 kilometres (497 miles) north of Edmonton, on the south shore of Great Slave Lake, in the District of MacKenzie, Northwest Territories (Figure 1).

The N81 deposit is located about 22.5 kilometres (14 miles) west of the Pine Point Mines Ltd. millsite. It was discovered in 1981, during a reconnaissance Induced Potential survey of an area previously surveyed in 1969. Published ore reserves were 3.0 Mt at a grade of 12% Zn and 7% Pb (Rhodes et al., 1984).

Topographically, the area is essentially flat, with a very gentle slope northwards towards Great Slave Lake. Surface drainage by streams is virtually non-existent, although the Buffalo River flows into Great Slave Lake through the western portion of the mining district. The terrain is dominated by muskeg, swamps, and by numerous small ponds and sinkholes. Drainage is further inhibited by

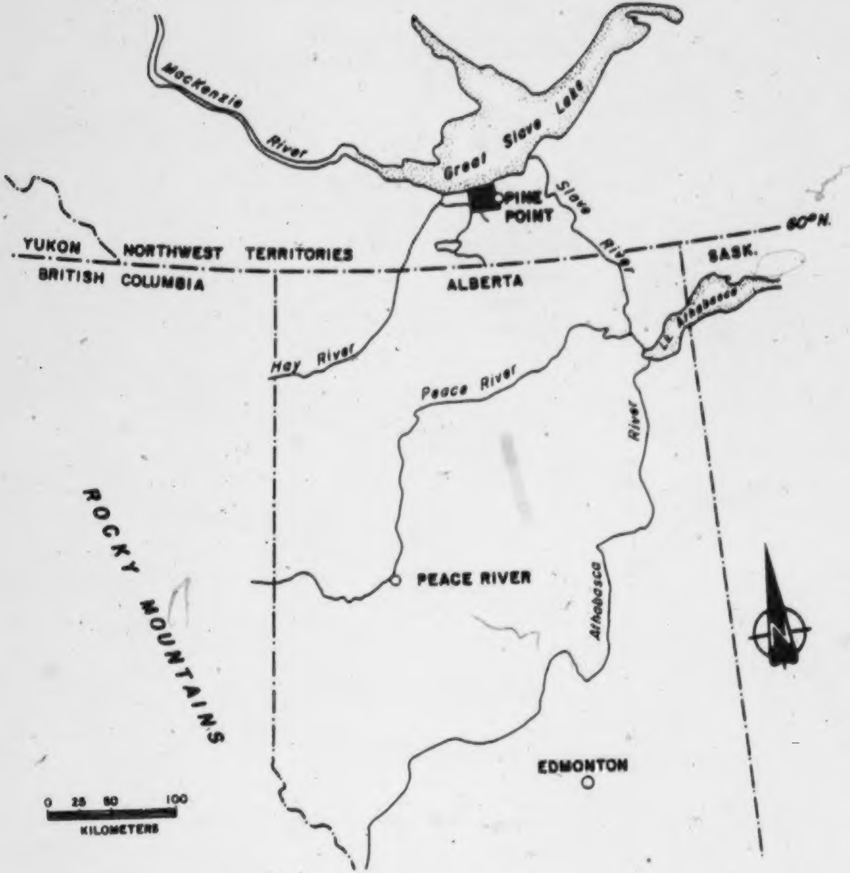
MacKenzie River
Great Slave Lake
PINE POINT
Slave River
60°N.
YUKON
NORTHWEST TERRITORIES
BRITISH COLUMBIA
ALBERTA
SASK.
Lk. Athabasca
Hay River
Peace River
River
Athabasca
PEACE RIVER
ROCKY MOUNTAINS
EDMONTON
0 25 50 100
KILOMETERS
N

Figure 1. Location of Pine Point Mining District

several east-west trending sand and gravel ridges believed to be ancient strand lines of Great Slave Lake.

The area is blanketed by extensive Pleistocene and Recent sediments, averaging approximately 20m (65 feet) in thickness. Bedrock exposures are extremely rare and mostly confined to the shore of Great Slave Lake.

The Pine Point district lies within the geologic region known as the interior platform, i.e. the stable cratonic interior of the North American continent (Figure 2).

The gently west-dipping sedimentary strata of the interior platform extend from their erosional edge against the Precambrian Shield to the Foothills Belt of the Cordilleran orogen. Overlying the Archean crystalline rocks are up to 600m of Ordovician and Devonian sediments. Within these sediments, a narrow (10 km wide) linear buildup of carbonate facies with a maximum thickness of 200m formed a "barrier complex" (Rhodes et al., 1984). This barrier, trending 065°, separated two depositional basins - the MacKenzie Basin to the north and west, in which predominantly shales and shaly

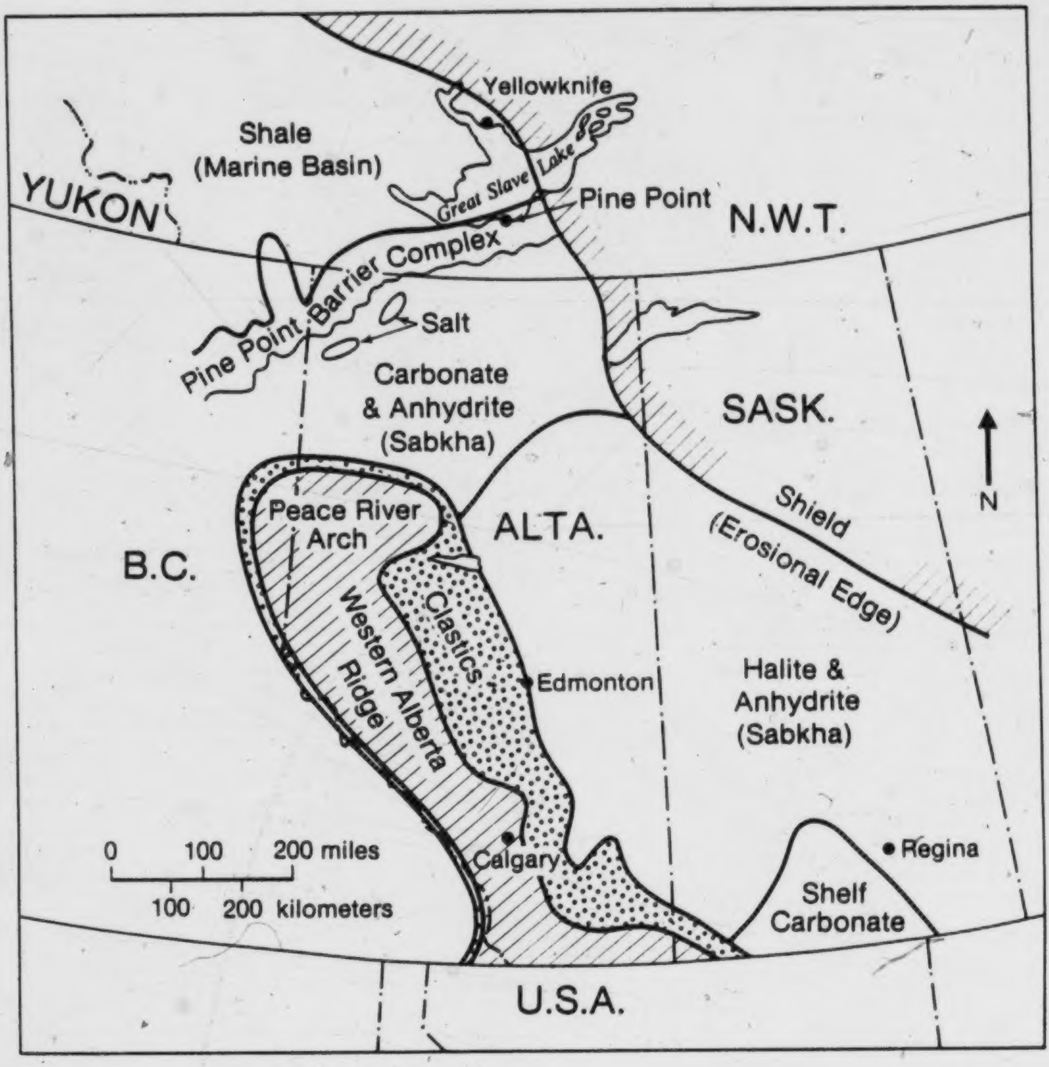
Yellowknife
Shale
(Marine Basin)
YUKON
Great Slave Lake
Pine Point
N.W.T.
Pine Point Barrier Complex
Salt
Carbonate
& Anhydrite
(Sabkha)
SASK.
N
Shield
(Erosional Edge)
Peace River
Arch
ALTA.
B.C.
Western Alberta
Ridge
Clastics
Edmonton
Halite &
Anhydrite
(Sabkha)
0 100 200 miles
100 200 kilometers
Calgary
Regina
Shelf
Carbonate
U.S.A.

Figure 2. Regional Location of Middle Devonian Facies. (modified after Bebout and Maiklem, 1973: Grayston et al.,1964)

limestones were deposited, and the Elk Point Basin to the south, in which were deposited evaporites and lesser amounts of carbonates. The Pine Point base metal deposits are hosted by paleokarst[1] features within the carbonate "barrier complex".

1.2 **Stratigraphy**

In the Pine Point district the Precambrian basement of the Canadian Shield is unconformably overlain by 300 to 600m of clastic and evaporitic rocks of early Paleozoic age (Figure 3). Neither Silurian nor Lower Devonian strata are preserved in the region.

The Eifelian, Chinchaga Formation, consisting of evaporites, limestones and dolostones, rests unconformably upon Ordovician strata. The Chinchaga Formation is in turn succeeded by marine-platform carbonates of the Lower Givetian, Keg River Formation.

In Middle Givetian times, the aforementioned barrier developed above the widespread platform carbonates of the Keg River

---

[1] The term karst is used in this thesis in the broader definition of Quinlan (1972, p. 152) to denote any topographic or subsurface feature which was developed by dissolution either by meteoric waters, or by basinal fluids.

Age	Unit	Lithology
Upper Devonian (Frasnian)	Hay River Fm.	Calcareous shale, minor limestone
	Slave Point Fm.	Argillaceous limestones, minor dolostones, calcareous mudstones
Middle Devonian (Givetian)	Watt Mountain Fm.	Limestones and dolostones, waxy green mudstone interbeds
	Sulphur Point Fm.	Limestone of reefal and associated depositional facies, extensive coarse-crystalline dolostone (Presqu'ile), transitional into calcareous shale (Buffalo River Fm.) to NW and lagoonal and peritidal (evaporitic) facies (Muskeg Fm.) SE
	Pine Point Fm.	Fine crystalline dolostone of reefal and associate depositional facies; transitional into bituminous limestone to NW and lagoonal facies and peritidal evaporites (Muskeg Fm.) to SE.
	Keg River Fm.	Argillaceous dolostones and limestones
Middle Devonian (Eifelain)	Chinchaga Fm.	Anhydrite and gypsum, minor dolostones, limestones and mudstones

Figure 3. Stratigraphic column of Paleozoic formations Southern Great Slave Lake Area (modified after Kyle, 1981 and Skall, 1975)

Formation, separating deeper marine environments of the MacKenzie Basin, from restricted shelf/lagoonal facies of the Elk Point Basin. The barrier facies sequence includes the Pine Point Formation and the overlying Sulphur Point Formation (Figure 4). The Pine Point Formation consists of a calcarenite, overlain by a biostromal unit. These facies were synchronous with the open-marine facies developed north of the barrier and with the evaporitic facies to the south. The Sulphur Point Formation conformably overlies the Pine Point Formation and is generally composed of a bioclastic facies with locally-developed bioherms. Backreef, intertidal and subtidal units of the Muskeg Formation interdigitate with the Sulphur Point Formation.

The Sulphur Point units are separated from the overlying strata by a regional erosional unconformity. Skall (1975) postulated a marine regression in the Pine Point area, occurring between Middle and later Givetian times. He described a period of uplift of the "barrier complex" (to a level at least 30m above sea level) and the consequent development of a karsted erosional surface.

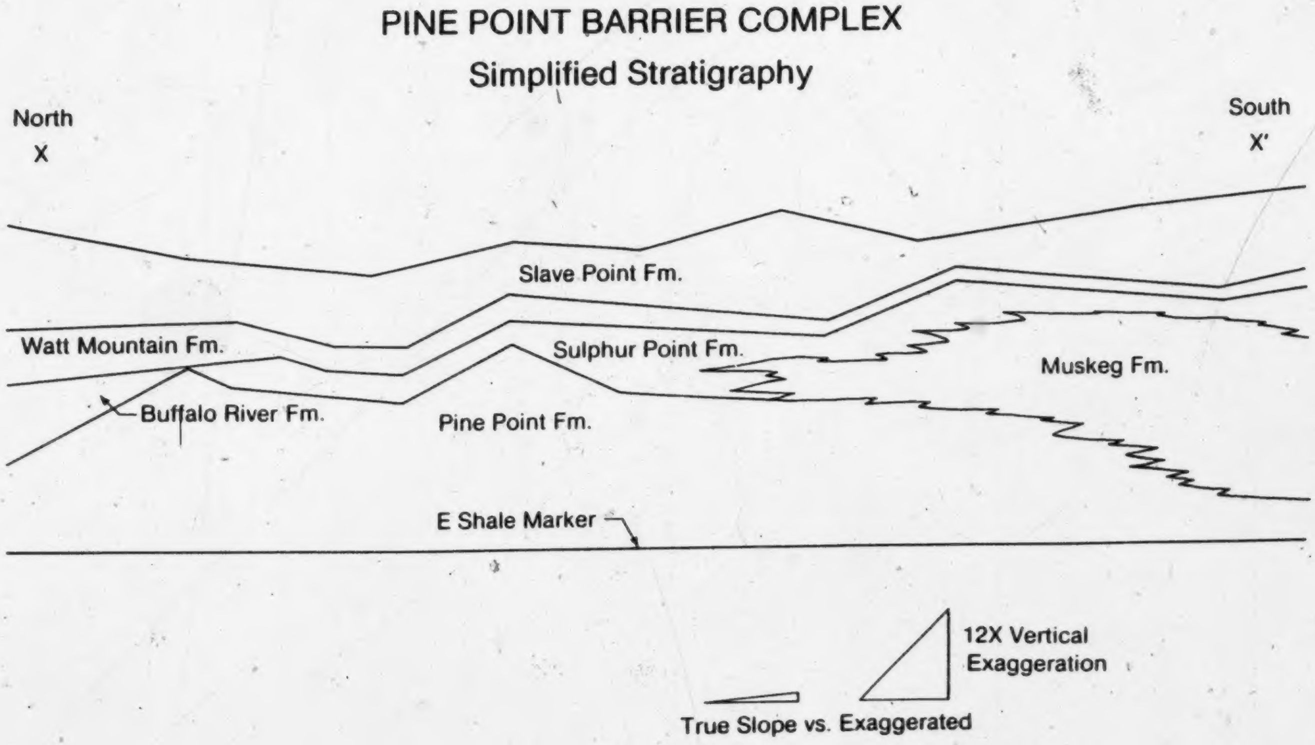
PINE POINT BARRIER COMPLEX
Simplified Stratigraphy
North
X
South
X'
Slave Point Fm.
Watt Mountain Fm.
Sulphur Point Fm.
Muskeg Fm.
Buffalo River Fm.
Pine Point Fm.
E Shale Marker
12X Vertical Exaggeration
True Slope vs. Exaggerated

Figure 4. Simplified stratigraphic cross-section of the Pine Point "Barrier Complex" (after the usage of Pine Point Mines Ltd.)

Following submergence of the "barrier complex", the Watt Mountain Formation was deposited unconformably upon the Sulphur Point/Pine Point complex. The Watt Mountain Formation consists of a highly variable sequence of shallow, platform-lagoonal lithologies, including micritic limestones, dolostones and algal carbonates. The phyllosilicate content of these sediments is high and a characteristic waxy, green claystone is a prominent lithological component.

The Watt Mountain Formation is conformably overlain by a series of platform carbonates of the Slave Point Formation. The Amco shale member is a dark, grey-green marl. This is overlain by the characteristically finely laminated "N" facies and by tidal sedimentary rocks of the "O" facies of the Slave Point Formation which display irregular, wispy, argillaceous partings and abundant intraclastic and flazer beds (the facies nomenclature utilized herein is after Skall, 1975).

The Paleozoic sequence dips gently to the southwest, due to a post-Mississippian tilting event.

1.3 Structure and Tectonism

The early exploration programs undertaken by Cominco (1948 onward) were based upon the premise that the major ENE - WSW Precambrian faults in the East Arm of Great Slave Lake (the McDonald Fault system) (Figure 5) . . . "although apparently dormant during Paleozoic times . . . may have provided structural control and a source of some ore-bearing solutions in some Post-Devonian period" (Campbell, 1966). Campbell also noted that the Precambrian faults in the East Arm of Great Slave Lake separated strongly contrasting magnetic domains that could be traced beneath the Paleozoic cover. These domains result from the faulted juxtaposition of non-magnetic Proterozoic metasediments against more magnetic Archean gneisses. Subsequent drilling across the projected trend of the Precambrian faults did fortuitously expand ore reserves, but provided no evidence to indicate that these faults extended into the mineralized Devonian sequence of Pine Point.

Many authors since Campbell have remarked upon the possibility of a genetic link between the strike of the McDonald fault system and

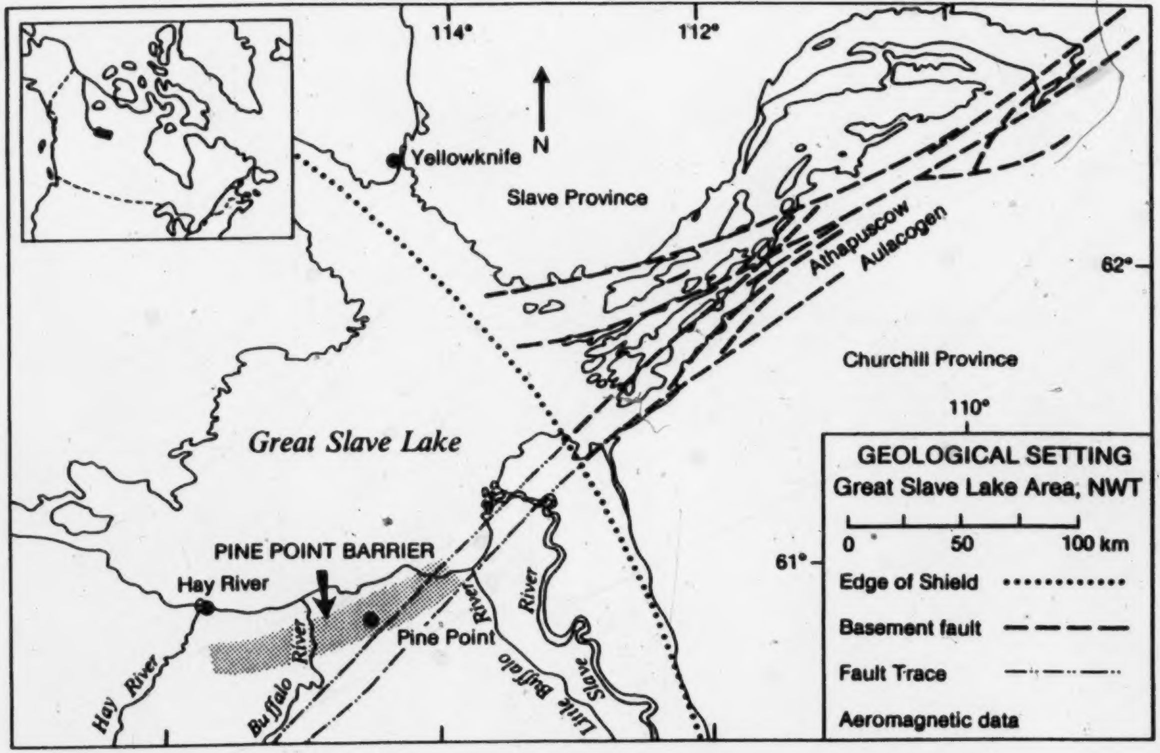
114°
112°
110°
62°
61°
N
Yellowknife
Slave Province
Athapuscow
Aulacogen
Churchill Province
Great Slave Lake
PINE POINT BARRIER
Hay River
Pine Point
Hay River
Buffalo River
Little Buffalo River
Slave River
GEOLOGICAL SETTING
Great Slave Lake Area, NWT
0
50
100 km
Edge of Shield
Basement fault
Fault Trace
Aeromagnetic data

Figure 5. Regional geological setting of the Great Slave Lake area illustrating the relationship between basement faults and the trend of the Pine Point "Barrier Complex" (modified after Kyle, 1977, Norris, 1965 and Hoffman et al., 1964)

the trend of the "barrier complex". Arguments both for and against the role of such ancient basement structures in the control of Paleozoic sedimentary facies are summarized in Rhodes et al., 1984. Skall (1975a) postulated three hinge lines, termed the south, main and north hinges, respectively, which paralleled basement faults during Middle Gevetian times. Skall suggested that these hinge lines influenced the development of the barrier facies.

Examination of the E-shale horizon of the Keg River Formation, along with detailed studies of more local marker horizons, such as the base of the Buffalo River Formation, have yet to demonstrate the presence of major faults or folds (Rhodes et al., 1984).

Structural contour maps of the district, apart from reflecting the regional westward tilt of strata, reveal gentle synformal-antiformal undulations of both N-S and E-W trends (Figure 6). These structures are of low amplitude, with 5-20m elevation differences over horizontal distances of several hundred metres. Most of this deformation apparently postdated both E-shale and Amco shale deposition, since the same structures are mirrored in both marker

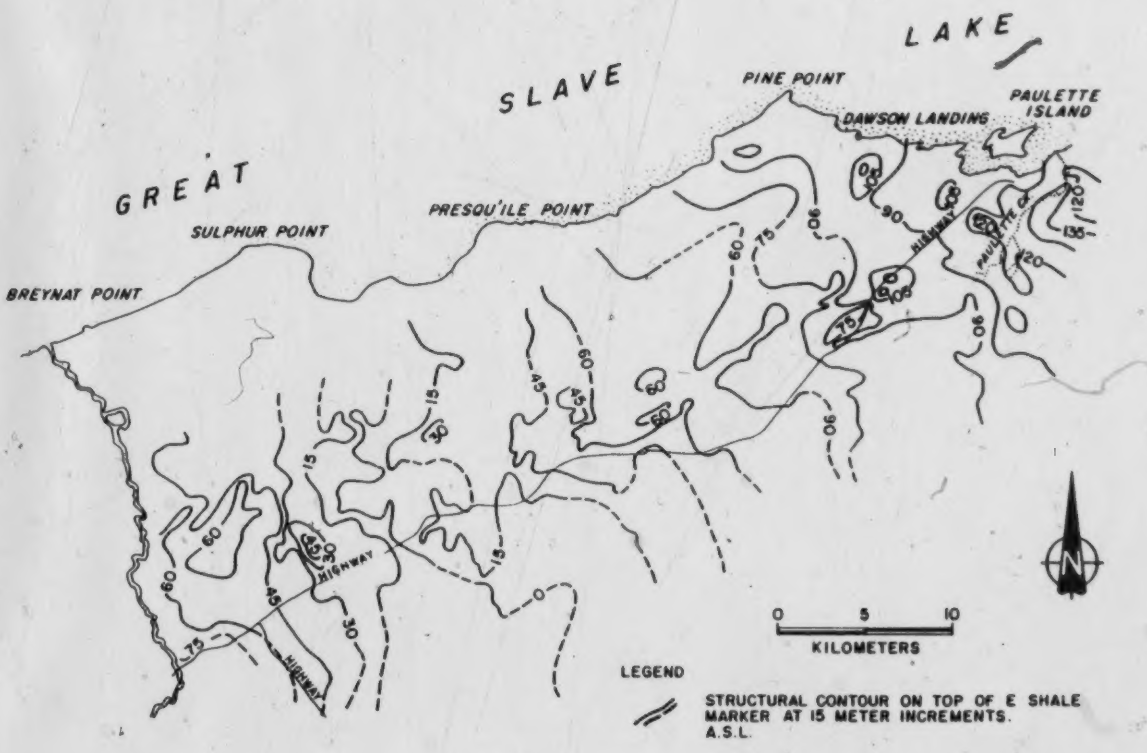
GREAT SLAVE LAKE
PAULETTE ISLAND
PINE POINT
DAWSON LANDING
PRESQU'ILE POINT
SULPHUR POINT
BREYNAT POINT
HIGHWAY
PAULETTE
N
0
5
10
KILOMETERS
LEGEND
STRUCTURAL CONTOUR ON TOP OF E SHALE MARKER AT 15 METER INCREMENTS. A.S.L.
0
15
30
45
60
75
90
105
120
135

Figure 6. Structural contours for the top of the E-shale Marker (modified after Rasmussen, 1981)

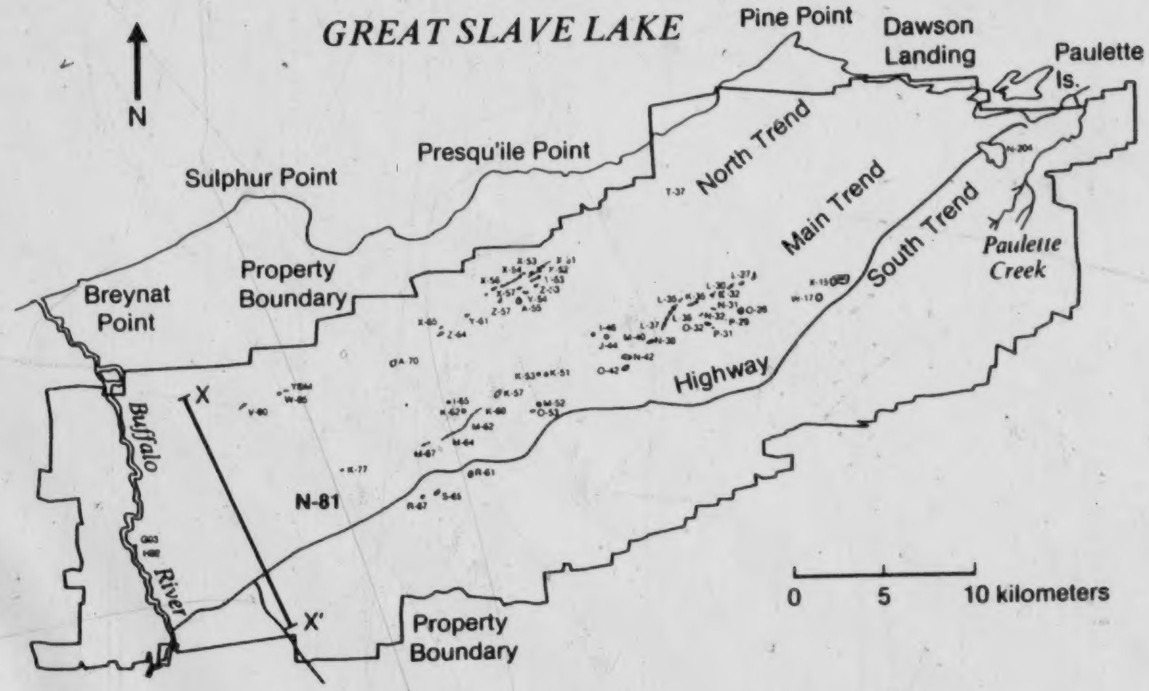
GREAT SLAVE LAKE
N
Pine Point
Dawson Landing
Paulette Is.
Presqu'ile Point
Sulphur Point
Breynat Point
Property Boundary
North Trend
Main Trend
South Trend
Paulette Creek
Highway
Buffalo River
X
X'
N-81
Property Boundary
0
5
10 kilometers
T-37
X-53
X-54
X-56
X-57
Y-52
I-53
Z-57
A-55
Y-61
X-65
Z-64
A-70
L-37
L-30
L-35
K-32
N-31
O-28
L-36
N-32
P-29
L-37
O-32
P-31
I-46
J-44
M-40
N-38
N-42
O-42
K-53
K-51
K-57
M-52
O-53
I-65
K-62
K-60
M-62
M-64
M-67
K-77
R-61
S-65
R-67
V-80
W-85
K-15
W-17
N-204

Figure 7. Map of Pine Point Mining District showing deposits of Zn-Pb mineralization

horizons. Some of these structures appear to have influenced sedimentation in Ameo or older strata, and their initial development may have been coeval with the late stages of barrier development (Rhodes et al., 1984).

1.4 General Aspects of the Pine Point Deposits

Over eighty deposits of zinc-lead mineralization have been defined in the Pine Point district (Figure 7). They vary in size, geometry, metal content, textures and host-rock relationships. In size they range from roughly 100,000 tonnes to 15 million tonnes. Distribution of deposits is closely related to the Presqu'ile dolomite and to regions of karsting.

Skall (1975a) showed that the "Presqu'ile facies" did not correspond to a dolomitized reef core, as was previously assumed, but that this dolomitization is a pervasive, fabric-destroying alteration phenomenon which produces a very coarse-grained, porous dolostone.[2]

---

[2] The term Presqu'ile is used in this thesis to denote the above described alteration phenomenon. It must not be confused with its use in early literature as a stratigraphic formation.

The base-metal deposits are also clearly associated with karstic zones of enhanced permeability: brecciated and collapsed zones within the "barrier complex". The deposits are classified on the basis of their geometry into "tabular" and "prismatic" types. These geometries represent opposite ends of a spectrum and examples which fall between these two extremes are numerous.

1.4.1 **Tabular Karst Deposits**

Tabular karst is the most common karstic phenomenon at Pine Point. It occurs in a crudely strata-bound horizon coincident with the Sulphur Point/Pine Point contact. Rock dissolution at this horizon produced cavities ranging from narrow, small interconnected openings, resembling a sponge, to wide ramifying and laterally continuous channelways. The channelways form tabular Karst structures and contain the tabular deposits. Locally, major cavities or large cavern-like prismatic openings extend up from the tabular system. Some of these host chimney-like prismatic deposits and are discussed later.

At Pine Point the openings have been filled with clastic carbonate which is now dolostone. These dolostones range from massive to well-laminated and occasionally cross-laminated sands to breccias incorporating fragments of the surrounding and overlying sequences. These so-called "internal sediments" are interpreted as having been deposited by subterranean streams and to have been derived by dissolution crumbling, collapse, and mechanical and fluvial erosion and transport of the original rocks. As the solution cavities developed, they were progressively filled, in an ongoing cycle, such that the tabular openings probably never had vertical dimensions equal to the thickness of the fill now observed.

1.4.2 **Prismatic Karst Deposits**

Prismatic karst structures have resulted from instances of extreme karsting within the aforesaid tabular horizon. The parameters which localized these areas of greater solution are uncertain, but it is likely they coincide with zones of maximum structural weakness where enhanced jointing and fracturing increased porosity and permeability. Subtle structural highs are often associated with the prismatic deposits. Frequently these "highs" and their associated "collapse caverns" appear to be related to salt ridge/diapirs. These are discussed later.

Karsting of the original carbonate rocks is extremely variable in the tabular horizons, leading to moderate to substantial sagging and collapse of the overlying strata. In the extreme cases of prismatic karst this foundering and collapse can affect 50 to 100m of stratigraphy, resulting in thick accumulations of internal sediment at and above the tabular karst horizon, overlain by thick breccia accumulations. These breccia accumulations commonly show very fine comminution of the host rocks, grading upward into progressively larger and less-distorted blocks of original carbonate lithologies. These collapse zones, where sufficiently mineralized, constitute the prismatic orebodies.

1.4.3 **Sulphide Mineralization**

The sulphide mineralization at Pine Point comprises a simple assemblage of galena, sphalerite, and marcasite with some pyrite and pyrrhotite.

A number of sulphide settings are recognized:

i) replacement of internal sediments within collapse breccias
ii) open-space filling between breccia fragments
iii) impregnation and replacement of breccia fragments.

Sulphide textures are highly variable property-wide and suggest a number of discrete stages of mineralization.

1.5 Previous Work on the N81 Deposit and its Environs

The present state of knowledge of the geology of the Pine Point district owes much to the work of N. Campbell and H. Skall. The astute geological insight of Campbell (Campbell, 1957, 1966) resulted in the successful exploration and development of the Pine Point ore-field. Skall's lithostratigraphic classification (Skall, 1975a) provided a framework for all subsequent studies and for documentation of the geology of the district.

A great number of papers have been written both on the origin of Mississippi Valley-type deposits *sensu lato*, and on the Pine Point ore-field. Reviews dealing with such mineralization include: Rhodes *et al.*, (1984), Anderson (1983), Anderson and Macqueen (1982), Krebs and Macqueen (1984), Powell and Macqueen (1984), Macqueen and Powell, (1983). It is beyond the scope of this work to thoroughly review all the relevant contributions, but pertinent studies are cited throughout the text of the thesis.

The following discussion must be prefaced by stating that, there exists no concensus of opinion concerning the genesis of the spectrum of Mississippi Valley-type deposits, or of the deposits of the Pine Point district *sensu stricto*. Two main hypotheses concerning the source and the transport of metals have arisen from past work. Jackson and Beales (1967) performed an exhaustive study of the Pine Point ore-field, and cited this district as an example of a situation in which compaction-generated stratafugic fluids (bearing metals), migrated from a basinal source into a transmissive carbonate "barrier complex" where the fluids encountered sour-gas reservoirs and precipitation of metal sulphides ensued.

Krebs and Macqueen (1984) forwarded a contrasting hypotheses which postulated that the Pine Point deposits resulted from the fortuitous juxtaposition of several entities, namely:

i) warm, metal-bearing solutions arising from depth along the MacDonald Fault - associated hingelines
ii) fractured collapse-zones within the host-carbonate
iii) a local source of hydrogen sulphide, produced by organic matter/sulphate reactions.

Billings *et al*., (1969) showed that the subsurface waters of the Western Canada Basin, and by analogy the MacKenzie Basin, are not stagnant, nor do they migrate randomly, but rather through porous and permeable carbonate conduits. In the same study, material balance calculations indicated that sufficient volumes of leachable metals are today available to generate deposits of the magnitude of the Pine Point ores.

The source of the metals of the Pine Point ores has yet to be conclusively resolved. A number of studies including Rhodes et al., (1984), and Jackson and Beales (1967) arrived at the conclusion that the metals were probably transported in chloride-rich fluids expelled from the MacKenzie Basin. Noble (1963) demonstrated that water expelled from these argillaceous sediments could have acted as the metal-transporting fluid. The brines, as well as acquiring metals during diagenesis, may have also been enriched in metals prior to burial.

Sasaki and Krouse (1969), using sulphur-isotope data, determined the most plausible source of the sulphur of Pine Point ores to be the Middle Devonian sea-water sulphate. They suggested that this was probably provided in the form of connate solutions from the contiguous sabkha-type basin.

Roedder (1968) observed fluid-inclusion filling temperatures from crystalline sphalerite of the Pine Point district to be in the range of 51 to 97° C, and white "hydrothermal dolomite" (Fritz and Jackson, 1972) closely associated with the sphalerite had fluid-inclusion filling temperatures in the range of 90 to 100° C. Thus, this dolomite and some of the crystalline sphalerite, have anomalous temperatures of formation as compared with the estimated average maximum temperature (approximately 60° C) of the "barrier complex" (Macqueen and Powell, 1983).

Macqueen and Powell (op cit.) applied organic geochemical analyses of bitumen associated with Pine Point ores, towards the resolution of questions of temperature changes in the host-rocks and the deposits, as well as the role of organic matter in the precipitation of sulphide minerals. They reported the existence of local thermal anomalies, indicated by the occurrence of pyrobitumen derived from immature organic matter in the dolomitized and mineralized zones. They also suggested that in situ reduction of sulphate, constituted an attractive explanation for the altered bitumens and for the known sulphur isotope signatures.

The first documentation of the morphological and textural features of the N81 deposit itself was presented by K. M. Carter in Rhodes et al., (1984). At that time only a relatively small portion of the drilling program had been completed. It was recognized, however, that the N81 deposit represented a typical prismatic-style deposit, consisting of two penetrative lobes of vertical dissolution, the base of which lay in the paleokarst horizon. Also, in the case of the N81 deposit, a substantial portion of the collapses and ore extended well up into the Slave Point Formation and was overlain by up to 20m of barren caprock. Other prismatic deposits, located farther east along the barrier, occurred as subcrops and were partly eroded. Due to its stratigraphic position below subcrop, N81 provided a unique opportunity for study of a complete prismatic deposit, unaffected by glacial erosion.

1.6 Objectives

The intent of this thesis is the documentation of some of the principal aspects of the N81 carbonate-hosted base-metal deposit. The N81 deposit was selected for study due to its position below subcrop as well as the availability of samples and data from a very complete diamond drill program and careful documentation of geologic features exposed during the course of mining this deposit.

Specific objectives of this study include:

i) the descriptive documentation of the N81 deposit using diamond drill-cores and observations from open-pit exposures

ii) the documentation of the metalliferous and gangue minerals, via study of representative polished thin-sections

iii) the investigation of isotopic composition of the constituent rocks and minerals, with the aim of shedding light upon the physico-chemical environment of mineral deposition

iv) the development of an hypothesis modelling the origin and controls of the N81 deposit and of similar base-metal occurrences in the district.

1.7 **Methodologies**

The descriptions recorded herein are the culmination of lengthy observations made by the author over a four year period of employment by Pine Point Mines Ltd. As well as the data from the drill-cores presented in this thesis, information was gathered during mining of the deposit and via broader observational opportunities during the course of property-wide exploration programs.

Twenty-nine drill-cores (totalling approximately 3500 metres) were selected from the N81 mine area (Appendix 1). The cores were drilled by Pine Point Mines Ltd. during the course of the N81 ore-outline program, (1981-1985). The selected cores were from drill-holes located along a SW-NE longitudinal-section through the deposit, and three perpendicular cross-sections.

The cores were logged by the author, using a lithological classification developed by Pine Point Mines Ltd.'s geological staff. Samples were collected at approximately 0.75m (2.5 foot) intervals, over the entire length of each drill core. These samples were subsequently slabbed using a diamond saw, and one half preserved intact; opposing halves were used to make polished thin-sections (by Cominco Lab. personnel) and to provide the minerals required for the stable isotope analyses.

CHAPTER II

DESCRIPTION OF THE N81 DEPOSIT

The N81 deposit was epigenetically introduced into ground prepared by two penetrative lobes of vertical dissolution cutting the Middle Devonian carbonates of the Pine Point "barrier complex". The base of these dissolution cavities lay within a common, linear, paleokarst cave-system. Continued dissolution above the primary cave-system stoped upward into younger Devonian platform carbonates to develop two irregular, beehive-shaped caverns, filled by a chaotic mass of down-dropped blocks and finer clastic debris (Figure 8).

Each lobe of the deposit was roughly zoned from its periphery to core, and a succession of increasingly disordered breccias was encountered as the centre of each ore-body was opened up. A zone of crackle/mosaic breccia, (cemented by white and blue-grey

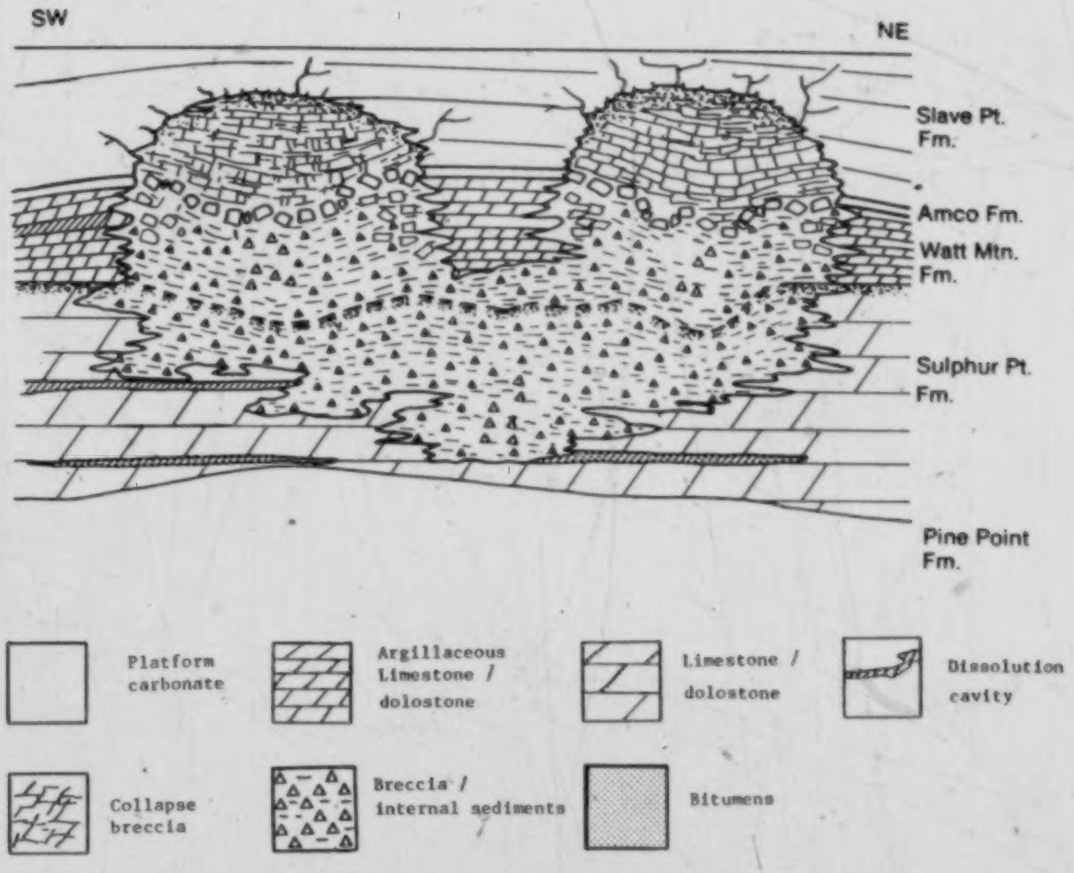
SW
NE
Slave Pt. Fm.
Amco Fm.
Watt Mtn. Fm.
Sulphur Pt. Fm.
Pine Point Fm.
Platform carbonate
Argillaceous Limestone / dolostone
Limestone / dolostone
Dissolution cavity
Collapse breccia
Breccia / internal sediments
Bitumens

Figure 8. Schematic long-section to illustrate the morphology, mineralogical- and lithological-zonation of the N81 deposit and its wall-rocks

dolosparite, calcite and native sulphur) surrounded a core of rubble-breccia (Figure 9). The most chaotic lithologies were found in the core of each lobe, and it was here that the highest grades of ore were mined. The ores of the N81 deposit were aggregates of spalerite, galena and iron sulphides (predominantly marcasite and pyrite).

Three main sulphide settings were recognized within the N81 deposit, namely:

i) massive replacement of platform carbonates
ii) open-space filling in the barrier carbonates
iii) replacement of internal sediments in the paleokarst channel.

Sulphide mineralization in those portions of the deposit corresponding laterally to the platform carbonates of the Slave Point and upper Watt Mountain Formations were very fine-grained and dense. These relatively massive sulphides displayed palimpsest sedimentary features of the original carbonates and carried pseudomorphs of earlier minerals, and as such were clearly replacive. In most of this zone virtually none of the carbonate host was preserved and ore grades commonly exceeded 30% combined Pb and Zn (Figures 10A and 10B).

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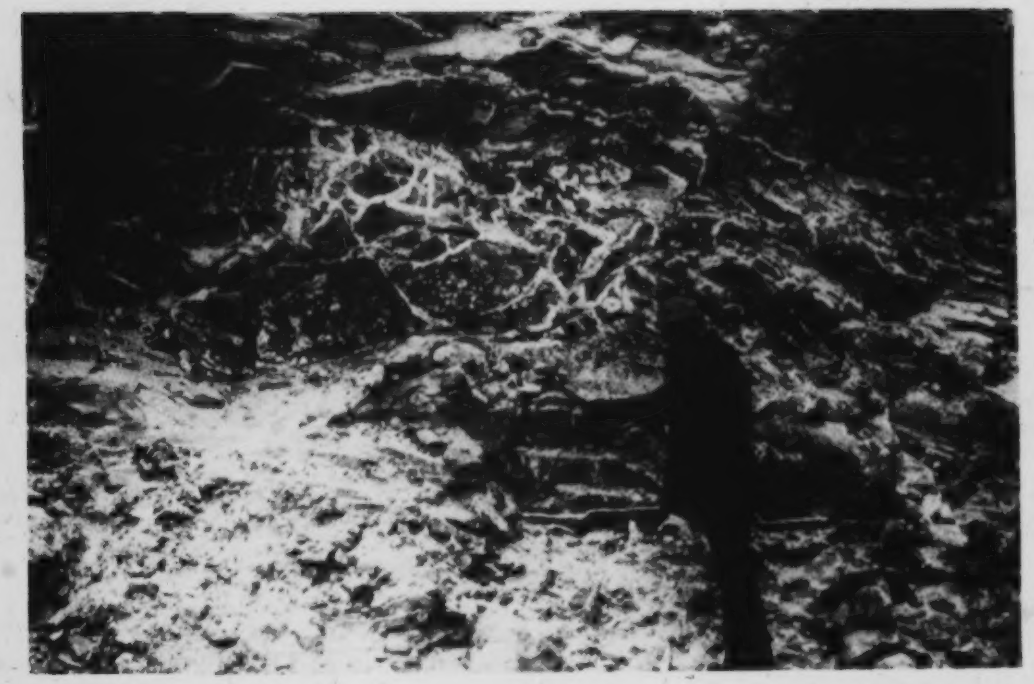

Figure 9. Crackle/mosaic Breccia, (cemented by white and blue-grey dolosparite, calcite and native sulphur)

With increasing depth in each lobe, the aforesaid replacement by sulphide became less complete. Colloform textures and remnant stalactities, indicative of open-space filling were prevalent (Figure 11).

Within the paleokarst cave-system, below the lobate sectors, breccias were underlain by granular internal sediments which were also highly mineralized. These internal sediments were usually brecciated with random bedding inclinations (Figure 12).

The contact between cavity-filling sulphides and adjacent dolostones was commonly abrupt, but locally, a pervasive replacement of breccia fragments and internal sediments adjacent to open-spaces filled by sphalerite was common. The effect was usually limited to a few centimetres and decreased away from the contact with the cavity-filling sulphides (Figures 12 and 13).

Although iron-sulphide minerals were ubiquitous in the deposit, an iron-sulphide "shell" (1.5 to 3.0m thick) surrounded the ore zones. Assays show the iron content of this "shell" commonly exceeded 35% (Figure 14). When this zone was initially opened up, iron sulphides oxidized at such a rapid rate that spontaneous combustion occurred,

Figure 10A. Drill-core of massive sulphide replaced Slave Point Fm.

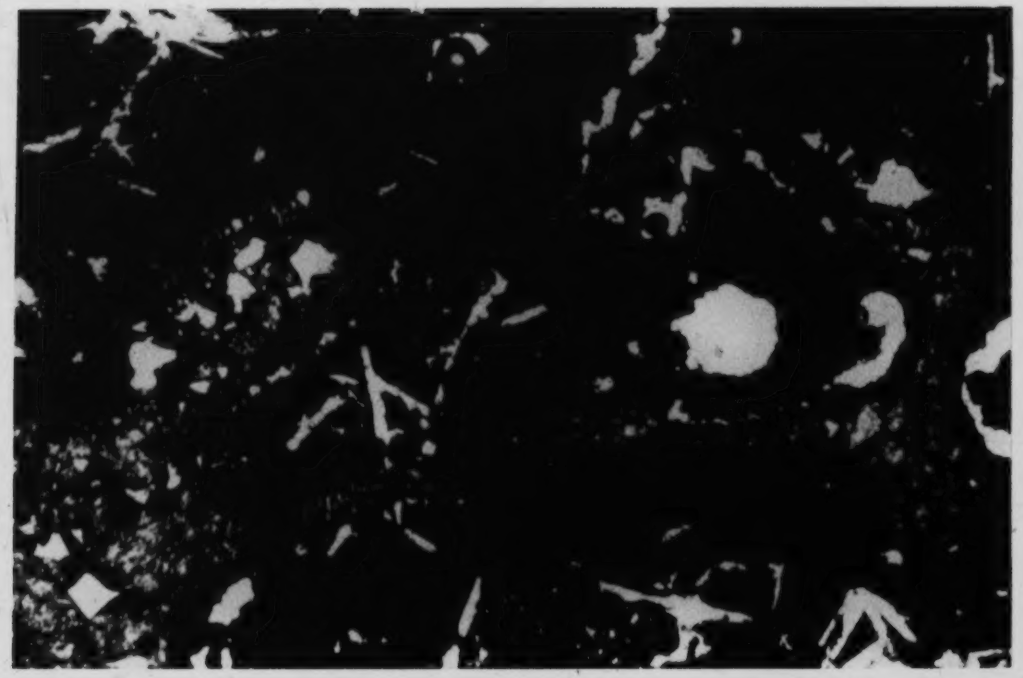

Figure 10B. Polished thin-section from sample in Fig. 10A, displaying pseudomorphs after sulphate minerals.

Figure 11. Colloform sphalerite, indicative of open-space fill.

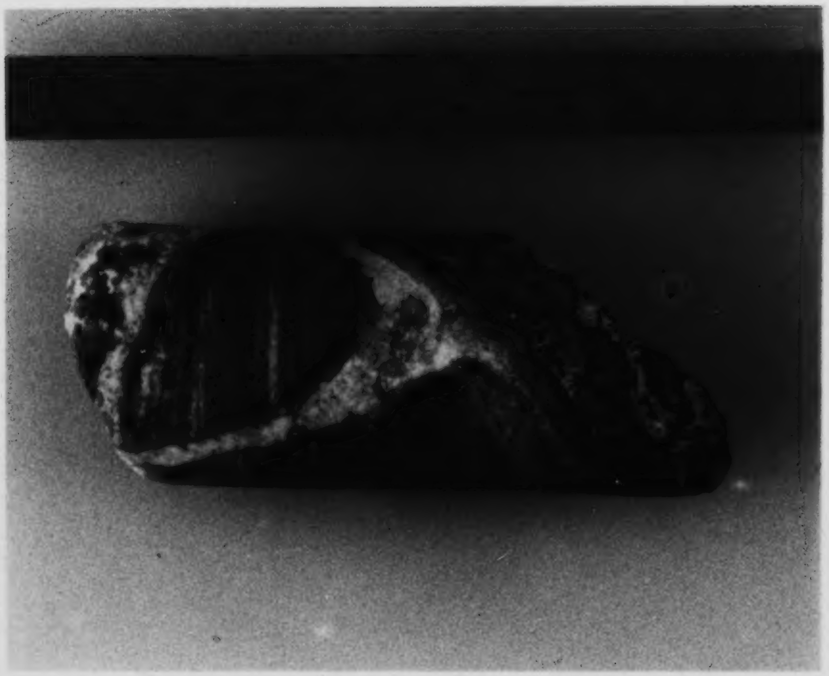

Figure 12. Brecciated internal sediments showing pervasive sphalerite replacement of fragments.

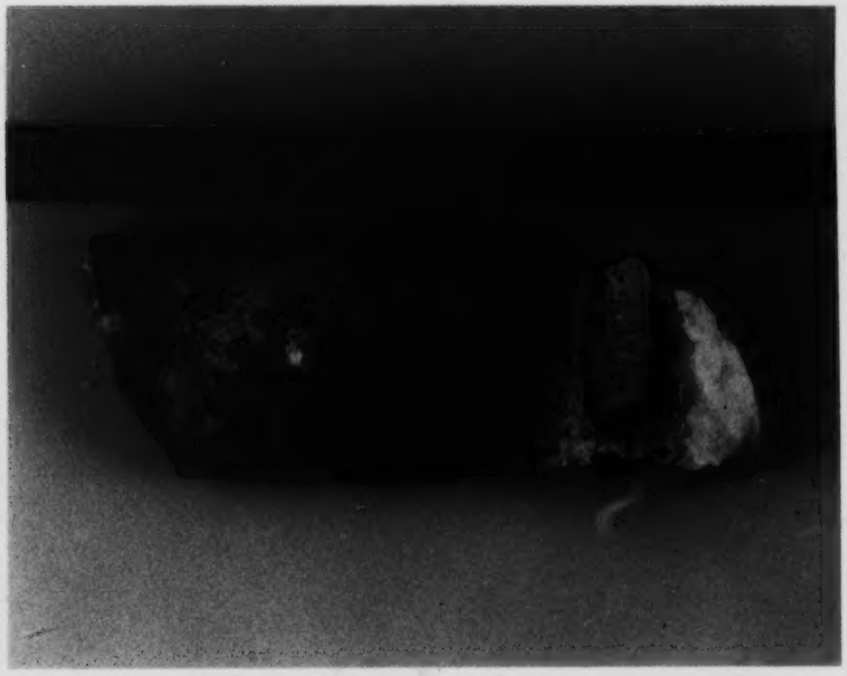

Figure 13. Pervasive sphalerite replacement of breccia fragments and internal sediments adjacent to open-spaces filled by sphalerite.

and portable oxygen supplies were necessary for workers in the pit.

The Amco shale horizon, in the vicinity of N81, was almost (Figure 14). When this zone was initially opened up, iron sulphides oxidized at such a rapid rate that spontaneous combustion occurred, and portable oxygen supplies were necessary for workers in the pit.

The Amco shale horizon, in the vicinity of N81, was almost entirely replaced by iron sulphides (Figure 15).

Native sulphur and bitumen also occurred as ubiquitous components of the N81 ores and adjacent host rocks. An exceptional amount of native sulphur occurred in the barren platform carbonates above the deposits. As well native sulphur occurred in association (Figure 14). When this zone was initially opened up, iron sulphides oxidized at such a rapid rate that spontaneous combustion occurred, and portable oxygen supplies were necessary for workers in the pit.

The Amco shale horizon, in the vicinity of N81, was almost with bitumen and calcite in the uppermost portions of the mineralized sectors and also in association with bitumen and calcite at the site of the erosional surface of the barrier carbonates (Figures 16A and 16B).

Figure 14. Handsample from zone of iron-sulphide replacement which enclosed the N81 deposit.

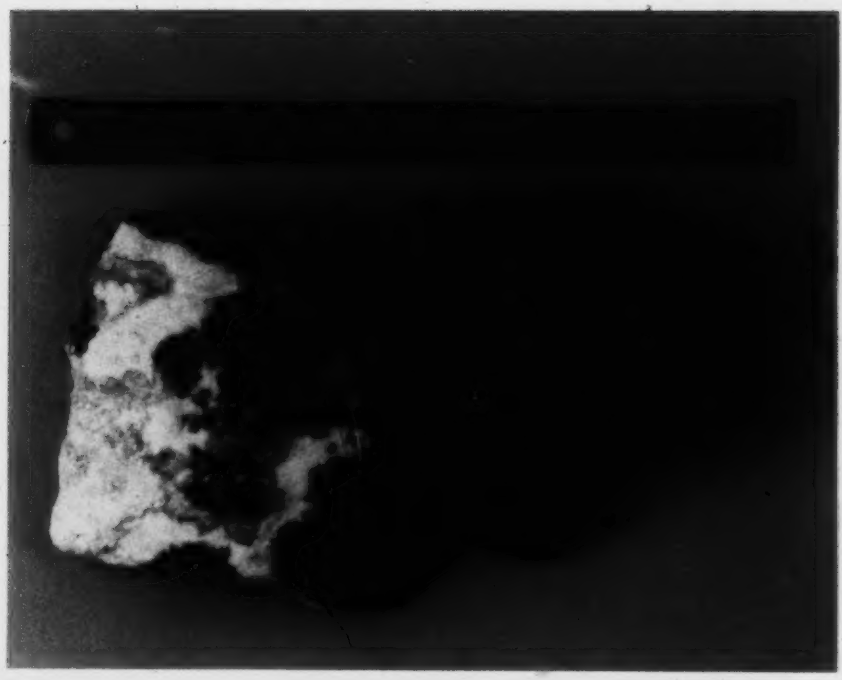

Figure 15. Brecciated Amco shale showing intense iron-sulphide replacement and cementation by locally derived internal sediments, calcite and native sulphur.

Figure 16A. Drill-core from zone of bitumen, calcite and native sulphur replacement at the top of the collapse zone.

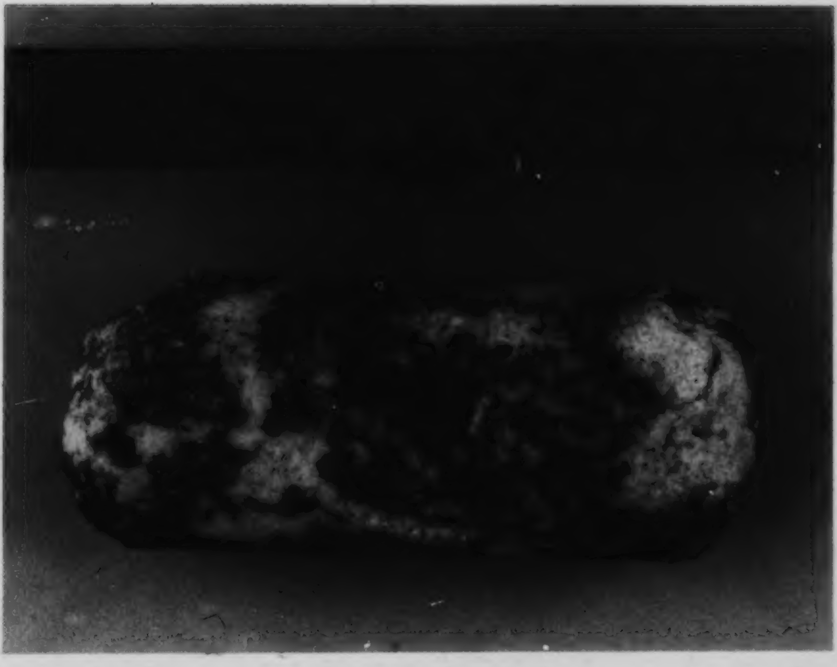

Figure 16B. Drill-core from bituminous horizon coincident with the Sulphur Point/Watt Mountain unconformity.

Detailed studies of the barrier carbonates indicate that local marcasite pockets (>50% FeS_2) may be correlated with bitumen-rich horizons, suggesting pockets of locally produced H_2S and subsequent precipitation of FeS_2.

CHAPTER III

PARAGENESES AND MINERALOGY

In order to document the parageneses, alteration and mineralogy of the N81 deposit, 139 polished thin-sections were studied. These were made from samples collected from outside the ore-zone, from the barren cap-rocks and from within the ore-zone.

The N81 deposit is characterized by two distinct phases of dolomitization, which were followed by deposition of sulphide minerals and finally by the precipitation of calcite. Presqu'ile-type dolomitization was apparently followed by precipitation of a hydrothermal dolosparite. Following the main mineralizing event, younger calcite cements were emplaced.

Fritz and Jackson (1972) concluded that the formation of the Presqu'ile dolostones took place as the result of subsurface mixing of meteoric and marine waters. They indicated that this could have occurred during the period of barrier emergence in pre-Watt Mountain time.

Skall (1975a) subsequently suggested that Presqu'ile-type dolomitization may be a later, post-middle Devonian event. He considered that the Presqu'ile-type dolostone may have been the result of alteration effected by warm, ascending solutions trapped beneath the relatively-impermeable Watt Mountain formation.

Neither this present study nor that of Krebs and Macqueen (1984) were able to identify distinct products of early, marine/fresh water mixing and late, hydrothermal events. Krebs and Macqueen suggested that the Presqu'ile-type dolostone and void filling dolosparite may be the product of a number of superimposed fluid events, due to both downward percolating meteoric and ascending hydrothermal waters.

Observations made during the course of this study indicate, as inferred by the above-mentioned studies, that Presqu'ile-type dolomitic alteration may have resulted from the secondary alteration of previously dolomitized carbonates. Warm, stratafugic brines, possibly related to the metal-bearing solutions, further altered the texture of the early diagenetic dolostones, through which they percolated, and deposited void-filling dolosparite.

Within the N81 ores, a variety of textures were preserved, including:

i) solid, monomineralic veins (fracture fillings)
ii) fractures and vugs filled with symmetrical and asymmetrical, botryoidal layering
iii) disseminated, individual, well-formed grains
iv) pseudomorphs after earlier minerals
v) crystals lining vugs.

3.1 **Iron Sulphides**

Iron sulphide minerals occur throughout the N81 deposit in all of the above forms.

A zone of intense dolospar replacement and fracture filling of a distinctive blue-grey color, encloses the N81 ore zones and occurs locally within the deposit (Figure 17). Thin-section studies revealed that the blue-grey colour is due to the presence of extremely fine intercrystalline marcasite.

Replacement of the Amco shale member and the massive, iron-sulphide 'shell' enclosing the deposit were discussed earlier. In the Amco replacement zone, these iron-sulphides occur as fine-grained, euhedral and acicular radiating pyrite grains intergrown with bladed marcasite. In much of the replaced Amco shale marcasite has been converted to pyrite.

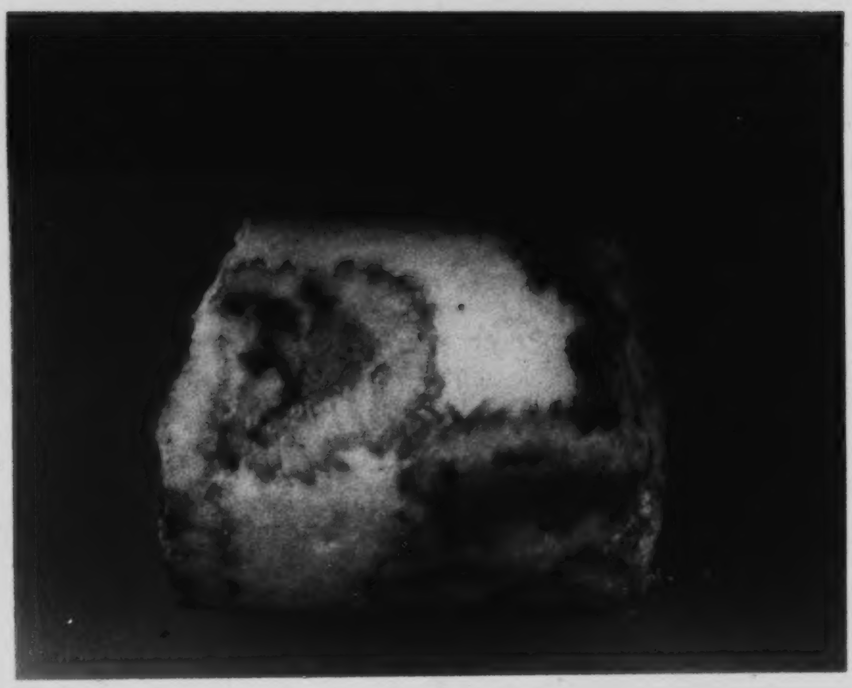

Figure 17. Drill-core displaying typical blue-grey dolospar and white calcite cements.

3.2 Sphalerite

Where sphalerite has filled open-spaces, it occurs as finely-banded, botryoidal crusts, up to several centimetres in thickness. These crusts coat breccia fragments and fill fractures and vugs (Figures 11 and 13). The botryoids are generally concentric and are frequently crenulated (Figure 18).

In transmitted light, the individual bands comprising the botryoids vary in colour from almost colourless through amber-yellow to very dark reddish-brown and black. The white bands have a porcelain-like lustre but the coloured bands show crystal aggregates whose components are elongated, normal to the bands. Individual crystals frequently cross thin colour-bands. According to Roedder (1968) who described similar features in the sphalerite of the deposits in the district, these textures are possibly the result of precipitation as minute druses of euhedral crystals.

Commonly, the banded, botryoidal masses of sphalerite have been covered by coarsely-crystalline, euhedral sphalerite grains. Study of these grains in thin section, revealed intensely-coloured zones from colourless through yellow to brilliant orange. As well,

Figure 18. Polished thin-section showing botryoidal sphalerite. transmitted light. (4X mag.)

they often display a subtle colour-zonation parallel to the outline of the crystal.

Dolostone adjacent to open-space filling frequently contained disseminated, fine-grained, light-yellow sphalerite, which appears to be of a replacement nature (Figures 12 and 13).

The last stage of sphalerite formation appears to have overlapped with the precipitation of calcite near the end of the mineralizing event. Thin-section studies of coarse, crystalline sphalerite in the interior of calspar-filled fractures and vugs revealed very strongly-coloured euhedral crystals, zoned and occasionally twinned (Figure 19). The colours in these sphalerites were most intense and ranged from lemon-yellow through orange to red. Also, a most unusual purple variety was observed (Figure 20A and 20B). The colour of this purple variety is strongly reminiscent of fluorite and could lead to misidentification. However, these crystals are clearly optically continuous with adjacent colourless, yellow and orange varieties of sphalerite.

In the zones of massive replacement of strata by sulphides, the sphalerite is often very fine-grained and powdery. Local zones of a

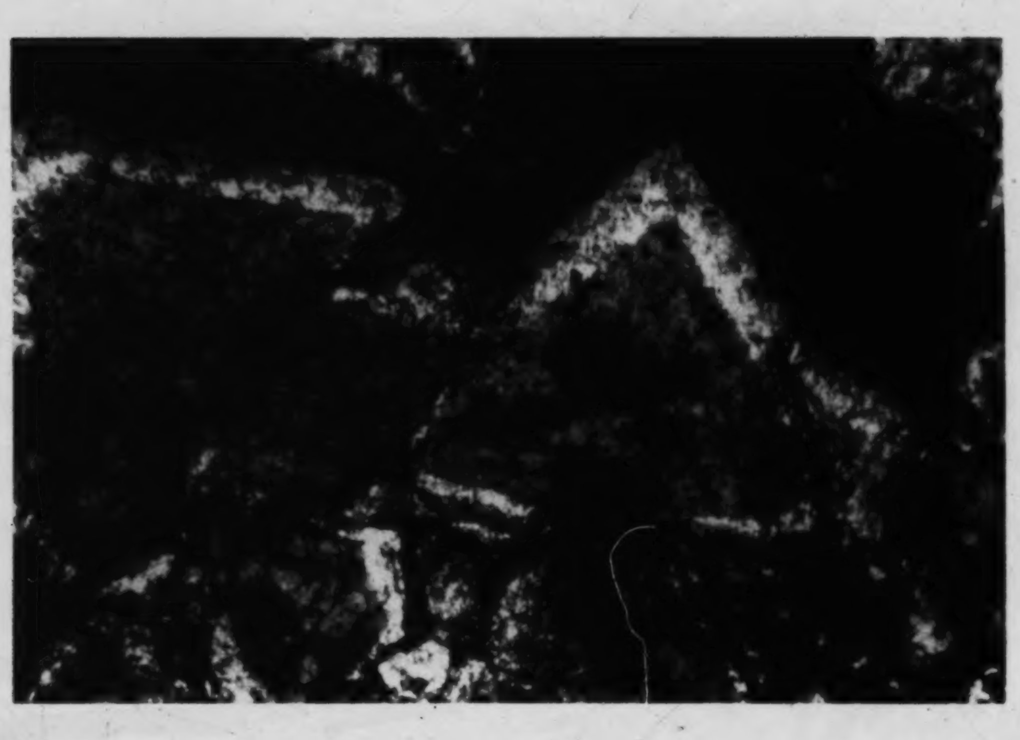

Figure 19. Coarse-crystalline sphalerite in the interior of calspar-filled fractures. (4X mag.)

"lacey open-work" texture appear to be the result of removal of very small limestone clasts, calcite or possibly of evaporite minerals.

3.3 Galena

Galena was apparently co-precipitated with sphalerite. Radiating skeletal galena crystals and elongated blebs occur enclosed in botryoidal sphalerite and perpendicularly transect the sphalerite bands (Figure 21). Galena cubes are also frequently enclosed within botryoidal sphalerite. Many sphalerite botryoids and crystals contain elaborate skeletal/dendritic galena crystals (Figure 22).

Coarse crystalline galena frequently occurs as monomineralic fracture-fill (Figure 23) and along 'interference surfaces' of botryoidal sphalerite masses. In the massive replacement ore-zones, galena is very fine-grained and these ores are often rather friable.

A late stage of galena precipitation resulted in galena cubes which are associated with calcite spar: lining vugs and fractures, and in pore-spaces within loosely-consolidated internal sediments.

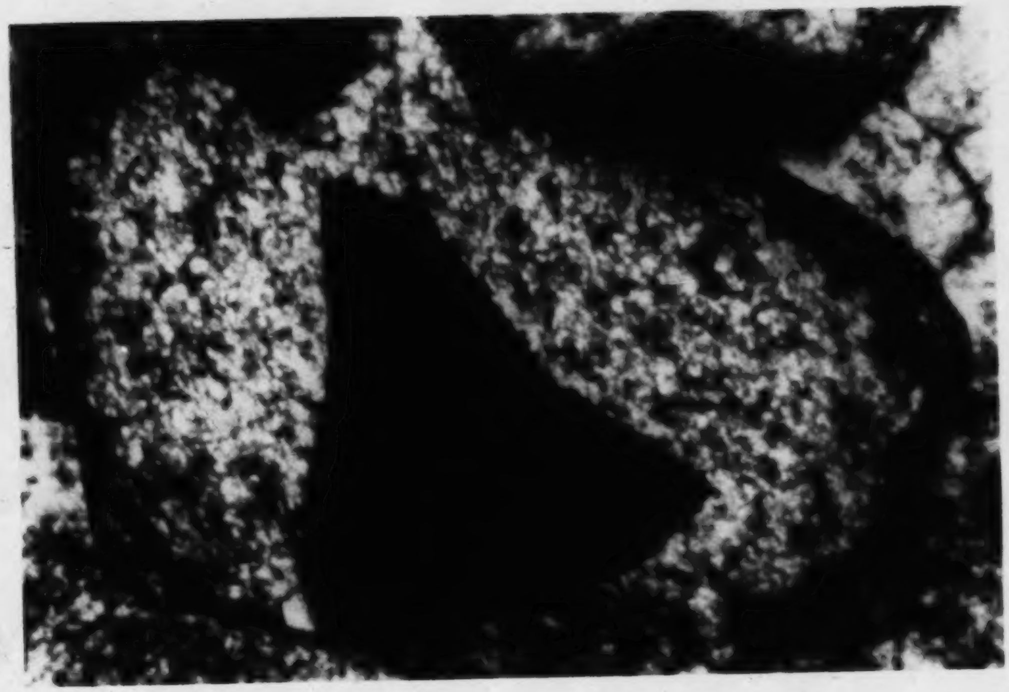

Figure 20A. Polished thin-section showing purple sphalerite. transmitted light. (4X mag.)

Figure 20B. Polished thin-section shown above at 8X magnification. Transmitted light.

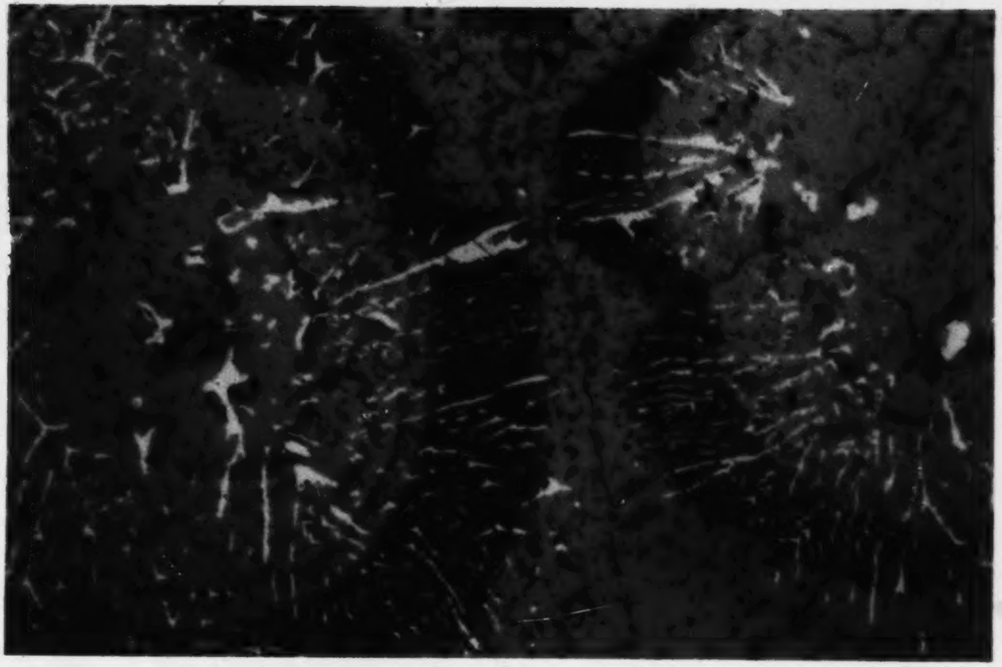

Figure 21. Radiating, skeletal galenacCrystals and blebs in botryoidal sphalerite. Reflected light. (4X mag.)

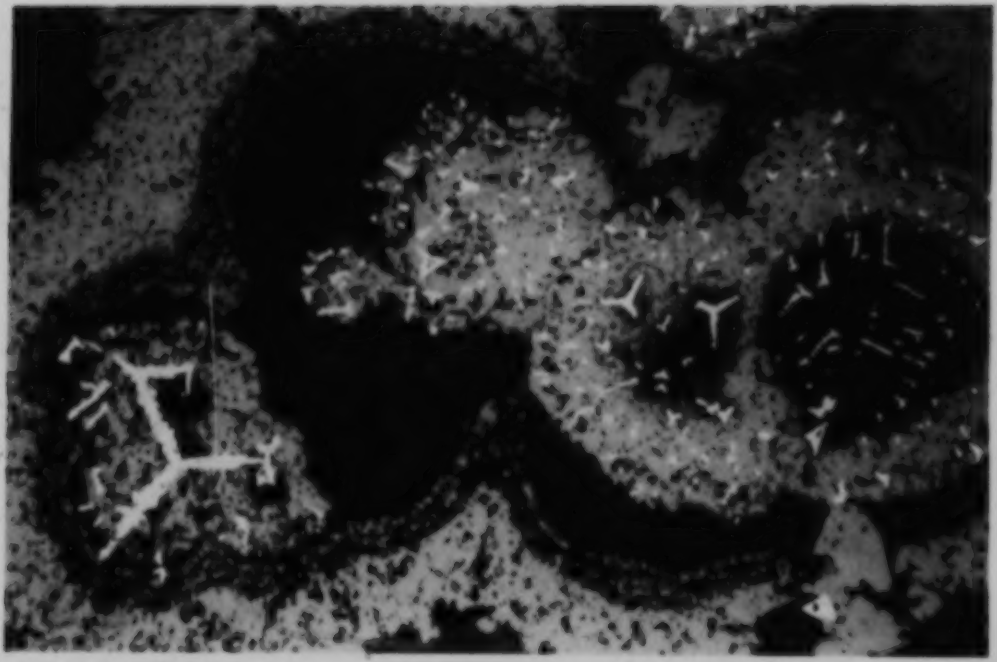

Figure 22. Sphalerite botryoids and crystals containing skeletal/ dendritic galena crystals. Reflected light. (4X mag.)

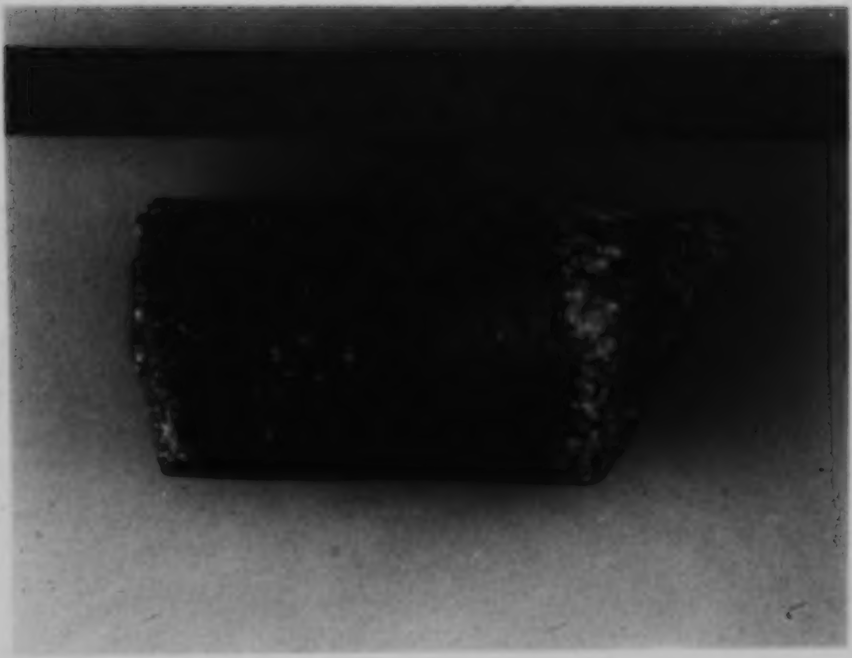

Figure 23. Massive galena fracture-fill.

CHAPTER IV

STABLE ISOTOPE STUDIES

A study of stable isotope ratios in the N81 ore-zone and its immediate environs was performed with the intent of revealing the genetic mechanisms which contributed to the development of the ores and gangues and with the hope that the paragenetic evolution might be further elucidated. Studies on C, O, and S isotopes were performed and the results presented in the following pages.

The most important recent paper concerning O and C isotope ratios in the Pine Point metallogenic district was that of Fritz (1969). This paper revealed a spectrum of causitive mechanisms and proposed an overall scenario for the "cycle of minerallization". However, one obvious question which arose from the database of Fritz's study concerned the validity of combining data from a whole spectrum of different deposits (the N42, O42, N32 and X15 deposits), which might have been neither coeval or consanguineous.

A number of previous papers had dealt with the sulphur isotope compositions of the Pine Point district's ore deposits, namely:

Folinsbee *et al.*, (1966), Evans *et al.*, (1968), Sasaki and Krouse (1969) and Powell and Macqueen (1984). However, once again these papers tended to deal with the Pine Point district *sensu lato* and did not focus upon specific deposits which might have represented unique, closed-systems during discrete time intervals.

Samples of both calcite and dolomite were analysed but not their mixtures. The purity of the samples was confirmed by x-ray diffraction. The samples were ground to less than 200 mesh size. About 30 mg of the sample was reacted with 100% phosphoric acid under vacuum at 50° C (McCrea 1950). The calcite samples were reacted for 12 to 24 hours, while the dolomites were reacted for 3 to 6 days. The CO_2 produced was collected in a liquid-nitrogen cooled trap in a vacuum line and analyses were carried out using a VG micromass 602D isotope ratio mass spectrometer.

The $^{13}C/^{12}C$ data are presented in per mil relative to the standard carbon from the Cretaceous belemnite (PDB). The $^{18}O/^{16}O$ data are presented in per mil relative to Standard Mean Ocean Water (SMOW) and are expressed by the formula;

$$^{18}O \text{ sample } ‰ = [(^{18}O/^{16}O) \text{ sample}/(^{18}O/^{16}O) \text{ SMOW} - 1]\, 1000$$

4.1 Carbon and Oxygen Isotope Results

The results of the C and O isotope study are presented in Table 4.1 and Figure 24. It is possible to recognize three distinct groups amongst the data, namely:

i) The calcitic limestones fall within the range of $\partial^{13}C$ -1.8 to 2.6 ‰ PDB and $\partial^{18}O$ + 21.5 to 22.0 ‰ SMOW (which compares well with Fritz's (1969) data for the Sulphur Point limestone at an average of $\partial^{13}C$ -1.9‰ PDB and $\partial^{18}O$ +21.2 ‰ SMOW).

ii) The "Presqu'ilized" dolostones (ie. metasomatically altered limestones) fall within a range of $\partial^{13}C$ 0.0 to +1.0 ‰ PDB and $\partial^{18}O$ +18.0 to 21.0 ‰ SMOW. Fritz (1969) found that some of his samples from such lithologies ranged as low as $\partial^{13}C$ 0.5 ‰ PDB and $\partial^{18}O$ +23.0 ‰ SMOW.

iii) The calcites which occupy late stages in the paragenesis (as vugs and veins of sparry calcite) show a marked scatter of values over the range of $\partial^{13}C$ -5.4 to +0.05 ‰ PDB and $\partial^{18}O$ +14.2 to +25.0 ‰ SMOW. Fritz (*op cit*.) also noticed such a scatter in late-stage calcites, but showed a much wider range of C and O isotope values, particularly with respect to more positive C isotope values.

The following interpretation of the C and O isotope data is forwarded as a possible starting point for the interpretation of the mechanisms behind the genesis of the N81 orebody:

Sample	Description	δ^{18}O(SMOW)	δ^{13}C(PDB)	Mineralogical Composition
(56A)0041	vug with ore and native S	+21.7	-4.1	100% cal
(56A)0047	fracture with ore, bitumin	+14.5	-5.4	100% cal
(56A)0098	fracture/collapse	+19.8	-1.5	100% cal
(56A)0112	fracture with ore	+23.0	-2.4	>90% cal
(65)0235	Presqu'ile, fracture	+20.8	+0.2	100% dol
(65)0240	Presqu'ile, fracture	+19.7	+0.0	>80% dol
(65)0241	Presquile, SRF texture	+19.4	+0.6	>80% dol
(65)0244	dolostone, marcasite, bitumen	+20.3	+0.2	100% dol
(65)251	Presqu'ile, SRF texture	+20.9	+1.0	100% cal
(65)0257	vug with native S	+18.7	-1.7	100% cal
(31A)0411	fracture	+13.3	-12.6	100% cal
(41)0956	vug with ore	+25.2	-1.6	100% cal
(41)0949	fracture	+23.3	+0.1	>90% dol
(47)1344	fracture	+18.2	+0.3	100% dol
	(rerun)	+18.7	-1.2	100%
(47)1358	vug	+14.8	-3.1	>90% cal
	(rerun)	+13.4	-6.3	>90% cal
(84)1059	replacement	+20.0	+0.1	100% cal
(84)1045	limestone, host-rock	+22.0	-2.5	100% cal
	(rerun)	+21.0	-3.9	100% cal
(84)1047	limestone, host-rock	+21.6	-1.9	100% cal
(32A)3415	replacement	+24.3	+0.1	100% cal
(32A)3415	fracture	+25.3	+0.3	100% cal
(32A)3362	breccia cement	+19.2	-5.5	100% cal
(32A)3367	limestone host-rock	+20.1	-4.1	100% cal

Table 4.1 Results of Carbon and Oxygen Isotope Studies

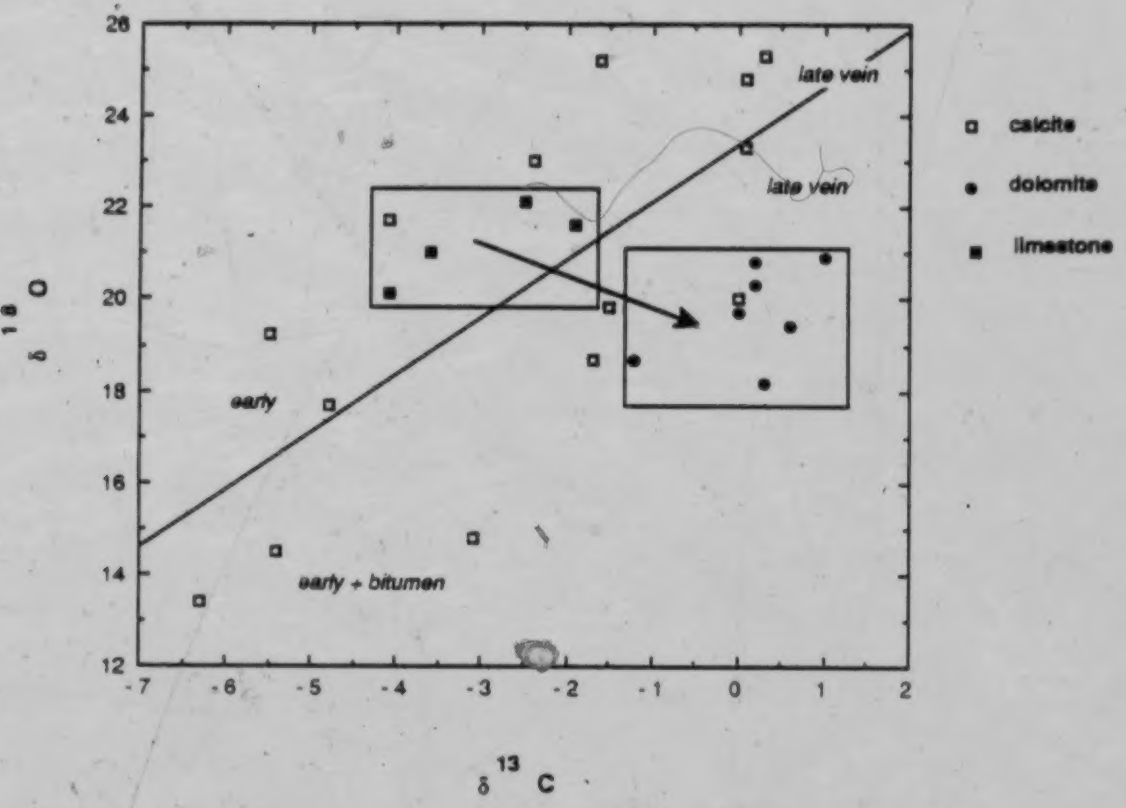

Figure 24. Carbon and Oxygen Isotope Results

i) the calcitic limestones were attacked and metasomatized by invading formation water which caused a negative shift in O isotope values.

ii) following the initial, wholesale invasion of the reservoir rocks by the formation water, bacterial degradation of the organic fractions in the system by sulphate-reducing bacteria commenced.

The observed occurences of native sulphur and residual bitumen associated with some of the late-stage calcites supports the first premise of the concept. However, the scatter of the calcite isotope data could also be due to a number of factors apart from the bacteriogenic effects namely:

i) temperature variations
ii) pH variations
iii) meteoric water influences
iv) changes in such controlling factors as fO_2 and the activity of bicarbonate and carbonate ions.

The author feels that the observed scatter of the calcite data could also be adequately explained by postulating the late-stage evolution of the N81 ore-system, based upon a limited reservoir of sulphur and oxygen. Thus a 'reservoir effect' in a bacteriogenic environment might account for some of the scatter of data in the following way:

i) The reservoir, formed within a diapiric sulphate-evapirite body was invaded by a slowly-penetrating fluid system bearing hydrocarbons and oxygenated water. The bacteria fed upon the hydrocarbons and utilized the sulphates in their metabolism.

ii) $(^{12}C>^{13}C)(^{16}O>^{18}O)_2$ was generated and precipitated isotopically 'light' calcites.

iii) As local reservoirs of carbon and oxygen consumption were depleted, the subsequent calcites would be characterized by Ca $(^{13}C>^{12}C)(^{18}O>^{16}O)_3$.

The first impression is thus that the N81 ores could have formed within a halite?/sulphate evaporite diapir which was slowly invaded by metal-bearing formation waters. As the salt dissolved and the waters invaded the diapir, sulphate-reducing bacteria attacked hydrocarbons, which might in part have been introduced by the invading waters. As the bacteria consumed local pockets of organic materials, and attacked and destroyed the evaporitic sulphates, they gave off isotopically light CO_2 and generated S, H_2S and HS^-. The latter two would pervade the reservoir and gradually react with the metal ions in the formation water, precipitating sulphides. In essence, this would be a series of sulphur-emitting (sulphurizing) cells which affected a metalliferous fluid system around them (thus the distinct zonation). If this was the actual case, the sulphur isotope data would be expected to reflect the bacterial contributions.

4.2 **Sulphur Isotope Results**

Sixteen samples of sphalerite and twelve samples of galena were separated from ores of the N81 deposit and analysed to determine their ∂^{34}S data; presented in Table 4.2 and Figure 25. The following initial observations can be made:

i) The complete data set ranges from ∂^{34}S +14.5 to 24.9 °/oo CDT with a mean of 17.8 °/oo and a standard deviation of 2.1 °/oo.

ii) The sphalerite ∂^{34}S °/oo values have a mean of +19.1 °/oo and a standard deviation of 1.9 °/oo.

iii) The galena ∂^{34}S °/oo values have a mean of +16.1 °/oo and a standard deviation of 1.1 °/oo.

Duplicate analyses of two sphalerite samples and two galena samples revealed a reproducibility of 0.40 °/oo and 3.27 °/oo and 0.6 and 1.49 °/oo respectively. One must therefore conclude that some minor error may underly both sets of data and might either be due to contamination by mutual inclusions or to some experimental procedure.

Sample		Number	$\partial^{34}S$	$^{\Delta}$(sph-gal)	T°C
5190	sph	147	21.66	4.56	....
	gal	148	17.10	....	....
	sph	149	24.93	7.89	....
	gal	150	17.04	....	....
5215	gal	151	15.61	....	....
	sph	152	19.61	4.00	154
3188	sph	154	17.77	3.21	203
	gal	155	14.56	....	....
5213	sph	156	18.62	....	....
	gal	157	14.51	4.11	148
	gal	170	16.00	2.62	255
3193	gal	158	15.32	2.74	245
	sph	158	18.06	....	....
5236	gal	160	18.53	0.42	....
	sph	161	18.95	....	....
5214	gal	162	16.42	1.79	....
	sph	163	18.21	....	....
6493	gal	165	16.31	....	....
	sph	166	19.03	2.72	....
	sph	167	20.28	3.97	....
5218	gal	168	16.99	2.55	262
	sph	169	19.54	....	....
5239	sph	171	17.39	2.48	....
	sph	172	16.99	....	....
	sph	173	18.59	....	....
	gal	174	14.91	....	....
5204	sph	175	17.73	....	....
5209	gal	176	16.52	1.18	....
	sph	177	17.70	....	....

Table 4.2

$\partial^{34}S$ and calculated T° for sphalerite-galena

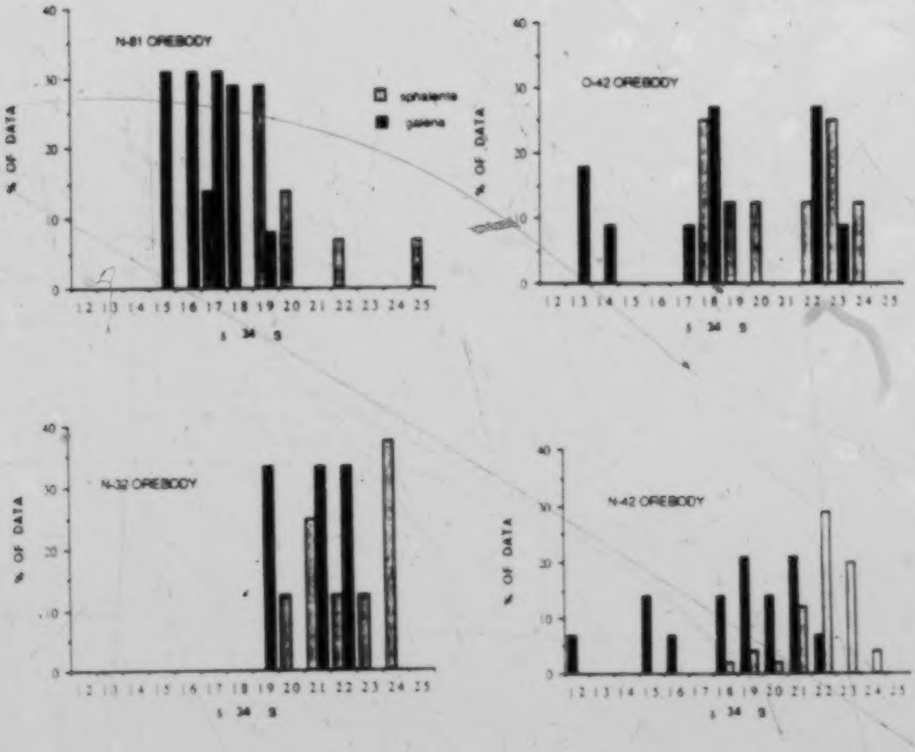

Figure 25: ∂S^{34} Variation in orebodies at Pine Point including the N81 deposit (after Sasaki and Krouse, 1969).

In all cases ∂^{34}S-sphalerite is greater than ∂^{34}S-galena and initially suggests an approach to isotopic equilibrium. However, Δsph-gal varies considerably and strongly suggests either that equilibrium was not achieved, or that pulses of different fluid temperatures were recorded. It is the author's opinion that the banded and partly replaced textures seen in the galena/sphalerite assemblages are strongly indicative of non-equilibrium conditions. Thus any attempt to place significance upon temperatures inferred by some of the galena-sphalerite "pairs" would be highly suspect.

4.3 The Origin of Sulphur in the N81 Orebody

For some time, it has been generally accepted that the sulphur of the sulphides in the Pine Point district was derived by reduction of pre-existing Devonian evaporitic sulphates (gypsum and anhydrite) in the carbonate sequence. Sasaki and Krouse (1969) postulated that the total destruction of the pre-existing sulphates labelled the sulphur isotopic composition of the sulphides. The sulphides appear to range, on average, from around $\partial^{34}S_{CDT}$ 18 to 20 ‰ and the anhydrites of the Elk Point Basin had ∂^{34}S values of 16 to 19 ‰ (Folinsbee et al., 1969, Sasaki and Krouse, 1969).

This reduction of evaporitic sulphate to sulphide ions is attributable to one or two of the following processes:

i) Bacterially-mediated sulphate reduction or bacterial sulphate reduction (BSR)

ii) Abiogenically-mediated sulphate reduction or thermal sulphate reduction (TSR).

Both of these reactions involve a net effect which may be summarized:

'pristine" hydrocarbons + SO_4^{+2}

"altered" hydrocarbons + bitumens + HCO^-_3 + CO_2 + Heat

In this exothermic reaction series, native sulphur will be produced if the geochemical cell becomes depleted in reactive hydrocarbons (BSR and TSR) or when hydrocarbons are not injected at a sufficiently high rate (TSR) (Machel,1987).

Within the system any alkaline earth ions (eg. Ca^{+2}, Mg^{+2}) will cause precipitation of calcite and dolomite, which would then replace and pseudomorph the original sulphates (Figure 9B).

The presence of base-metal ions would cause the precipitation of metalliferous sulphides, which in turn would lower the pH of the water and acidify the geochemical cell. Thus, carbonate wall-rocks and carbonate breccias would suffer extensive dissolution and the cell would be enlarged. Barite, cerrussite, fluorite could also be precipitated in such acidic environments.'

The fundamental problem in the Pine Point district is that some authors do not accept bacterial sulphate reduction as a plausible mechanism at the apparent high temperatures (100 - 130°C) of hydrothermal activity. Indeed, Powell and Macqueen (1984) and Macqueen and Powell (1983) postulated that no major bacterial sulphate reduction had taken place at Pine point and that the injection of hot, basinal brines was the underlying genetic mechanism responsible for many of the aspects of these base metal deposits. These authors proposed an injection of ~130 °C fluids to produce thermal anomalies around caverns within the Presqu'ilized carbonates. They felt that thermal sulphate reductions took place at 80 - 100°C when indigenous organics and sulphates reacted. The only biologic contribution was thought to be when late-stage bio-degradation of organics was effected as the ore-bearing zones were uplifted into regimes of oxygenated meteoric water.

Despite the fact that both Macqueen and Powell (op. cit.) and Machel (op. cit.) refute any contribution of bacterial sulphate reduction above 80 -100°C; Brock (1967), based on studies of ecosystems in natural hot spring environments, concluded the following:

> The upper temperature for life as we know it has not yet been defined. At Yellowstone, some bacteria live and grow essentially at the boiling point. Since increased hydrostatic pressure may permit growth at even higher temperatures there seems to be no reason why bacteria could not live in nature at any temperature where there is liquid water.

It is the present author's opinion that the sulphur isotopic composition could be adequately explained by reaction between Zn^{++} and Pb^{++} ions brought into the geochemical cell by warm stratafugic basinal brines. Karsting may have previously opened-up the carbonate system, allowing formational or meteroic water some access to sulphate and organic bearing evaporite diapirs. Early in the diagenitic sequence, H_2S and HS^- reacted with iron in the Amco shale to form FeS_2. Doming of the overlying shale beds and continuing deposition of calcite and FeS_2 in the overlying sediments tended to seal fractures by which H_2S could escape from the "dome". The evolving bacteriological system had a limited reservoir of carbon compounds, sulphates and oxygen, thus native sulphur and isotopically-light CO_2 were generated. Subsequent depletion of sulphates and metabolically acceptable hydrocarbons caused a series of reservoir effects, resulting in the generation of isotopically heavier CO_2. These two generations of CO_2 are now recorded in the indistinguishable late-stage calcites.

Thus, while thermal sulphate reduction may have played a role in some parts of the district, it is felt that the stable isotopic characteristics of the carbonates, galena and sphalerite in the N81 geochemical system are adequately explained by bacterial sulphate reduction processes.

CHAPTER V

ORE GENESIS

It has long been recognized that a major factor in the development of the Pine Point deposits was the transmissive paleokarst channel. The controls on location and development of the prismatic-style karst caverns have never been totally resolved. This author believes that mild diapiric activity (analogous to salt pillows), could have been a factor in both the localization and genesis of the N81 ores, and by analogy, of other prismatic-style deposits in the Pine Point district.

The following summary is forwarded as a plausible hypothesis for the localization and genesis of the N81 ores and as an explanation of the morphological, chemical and alteration characteristics of the deposit. The flow diagram (Figure 26) summarizes the events involved in formation of a N81-type prismatic-style deposit.

At some time following the deposition of the Slave Point

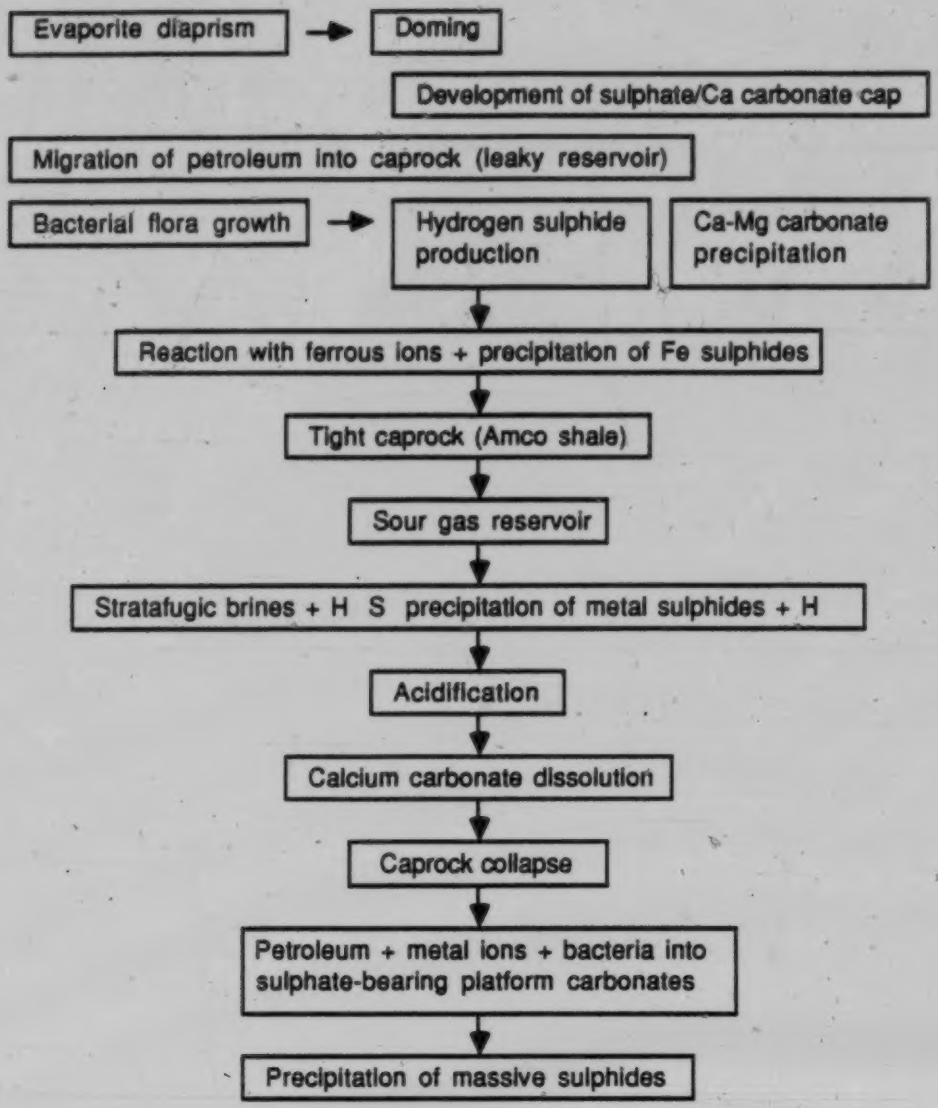
Evaporite diaprism
Doming
Development of sulphate/Ca carbonate cap
Migration of petroleum into caprock (leaky reservoir)
Bacterial flora growth
Hydrogen sulphide production
Ca-Mg carbonate precipitation
Reaction with ferrous ions + precipitation of Fe sulphides
Tight caprock (Amco shale)
Sour gas reservoir
Stratafugic brines + H S precipitation of metal sulphides + H
Acidification
Calcium carbonate dissolution
Caprock collapse
Petroleum + metal ions + bacteria into sulphate-bearing platform carbonates
Precipitation of massive sulphides

Figure 26. Possible sequence of events leading to some of the mineralogic and lithologic aspects of the N81 ores and their host-rocks

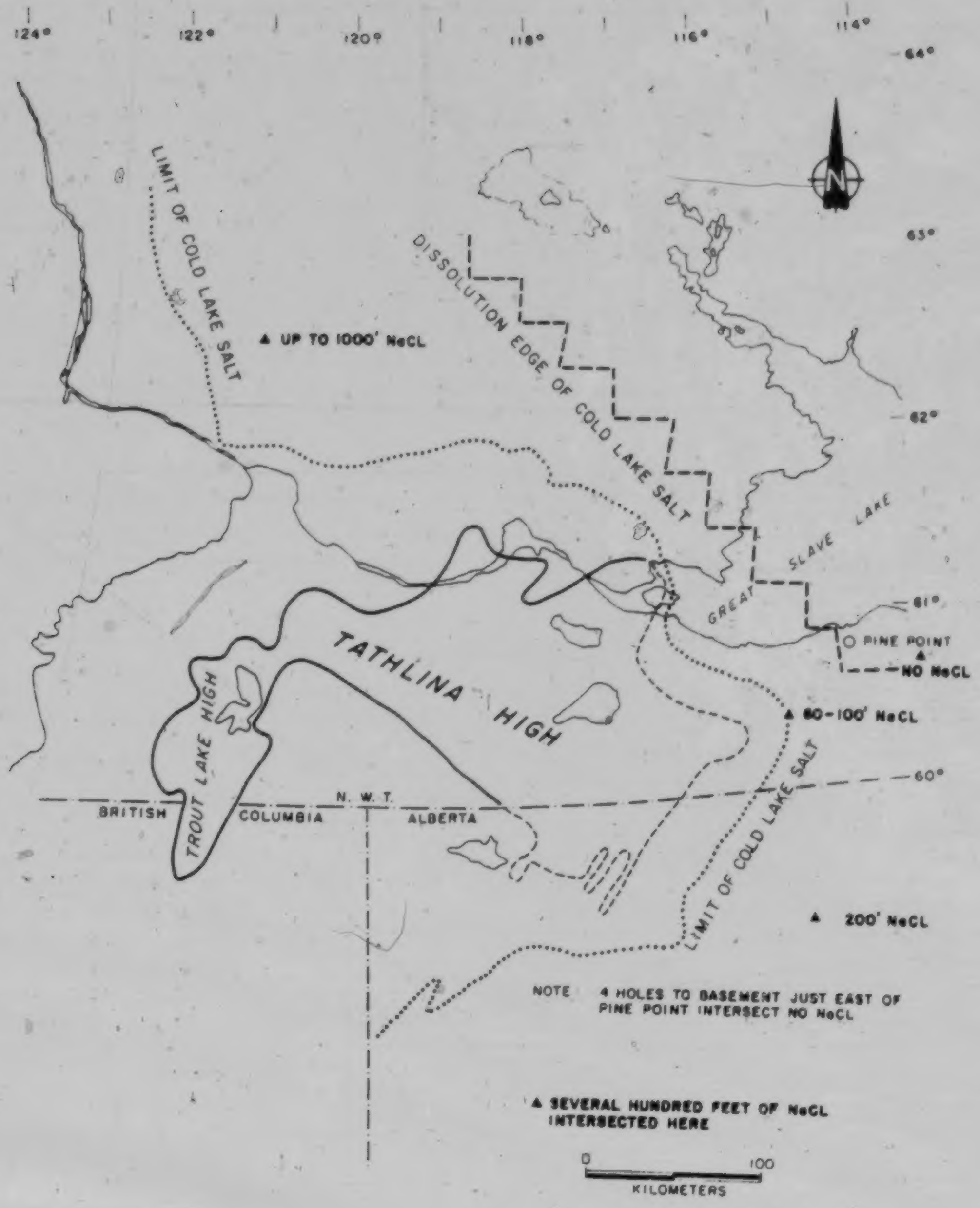
124°
122°
120°
118°
116°
114°
64°
63°
62°
61°
60°
N
LIMIT OF COLD LAKE SALT
▲ UP TO 1000' NaCL
DISSOLUTION EDGE OF COLD LAKE SALT
GREAT SLAVE LAKE
○ PINE POINT
▲ NO NaCL
TATHLINA HIGH
TROUT LAKE HIGH
▲ 60-100' NaCL
N. W. T.
BRITISH COLUMBIA
ALBERTA
LIMIT OF COLD LAKE SALT
▲ 200' NaCL
NOTE 4 HOLES TO BASEMENT JUST EAST OF PINE POINT INTERSECT NO NaCL
▲ SEVERAL HUNDRED FEET OF NaCL INTERSECTED HERE
0
100
KILOMETERS

Figure 27. Dissolution and depositional boundaries of the Cold Lake Salt Formation, modified after Adams, 1979.

Formation, mild diapiric uplift (probably of the Cold Lake salt, Figure 27) resulted in a gently undulating regional topography. The first stage of N81 development corresponded to structural deformation related to this doming or warping of strata. A $CaSO_4/CaCO_3$ caprock was also formed at this time. Structural deformation permitted hydrocarbon migration into the dome area and bacterial/organic reduction of sulphate ensued. The H_2S produced, reacted with available ferrous iron to produce FeS_2. This is believed to be the cause of the extensive FeS_2 replacement of the Amco shale and probably the iron sulphide "shell" surrounding the deposit. The aforementioned blue-grey dolospar, (coloured by fine-grained marcasite), adjacent to the deposit, also formed at this time. This extensive FeS_2 and dolomite precipitation effectively prevented the escape of H_2S and H^+. Incursions of Pb^{++} and Zn^{++} bearing brines into this sour-gas reservoir resulted in precipitation of the open-space filling sulphides and much sulphide replacement of "internal sediments". Continued precipitation of metal sulphides resulted in acidification of the geochemical cell and extensive dissolution of the hosting carbonates. Eventually, dissolution proceeded to such an extent that collapsing of the overlying carbonates occurred and the FeS_2-Amco caprock was breached, allowing H_2S, hydrocarbons, Pb^{++}, Zn^{++}, to saturate the now collapsed and brecciated platform carbonates. This phase of the mineralizing event resulted in the near-total replacement of the platform carbonates by sulphides.

The bitumen/sulphur/calcite rich zones at the top of the collapse structure and coincident with the Sulphur Point unconformity (as described in Chapter II, and illustrated in Figures 15A and 15B) suggest that hydrocarbons were density stratified in these sites atop a brine "pool".

CONCLUDING STATEMENT

The hypothesis presented through this study suggests a series of controlling mechanisms which determined the location and petrogenesis of the N81 deposit, and by direct analogy, of other prismatic-style deposits. Although previous studies went a long way toward providing broad explanations of metal origins and transport mechanisms, prior to the present study very little was understood about the exact local controls of any given deposit.

This study set out to build upon early work and to address this question in the specific case of the N81 deposit. The unique opportunity in this case was the fact that the author not only had access to the facilities and staff of the University of Alberta, but above all had a long term day-to-day exposure to the exploration and mining of the deposit in question, ie. the data base was not gathered during brief field excursions, nor were observations based only on a very limited exposure of the orebodies in the form of a single 'time slice'. This final point is addressed to members of the exploration and mining industry, who so often are deprived of the opportunity to involve themselves in what might appear at first sight to be studies of an esoteric nature. Few corporations have actively sponsored research and development projects in the past decades, with the notable exception of Western Mining Corporation of Australia, and with recent drastic cutbacks in government funding, we risk the total disappearance of such projects in the near future.

BIBLIOGRAPHY

Adams, D. H. 1979. Paleozoic Margin Study: Pine Point N.W.T., Pine Point Mines, unpublished report.

Anderson, G. M. 1983. Some geochemical aspects of sulphide precipitation in carbonate rocks, in Kisvarsanyi, G., Grant, S.K., Pratt, W.P., and Koenig, J.W. eds., International Conference of Mississippi Valley-type lead zinc deposits, Rolla Missouri, University of Missouri, pp. 61-76.

Anderson, G.M. and Macqueen, R. W. 1982. Ore deposit models - 6 Mississippi Valley - type lead zinc deposits: Geosci. Canada, v.4, pp. 108-117.

Bebout, D. G., and Maiklem, W.R. 1973. Ancient anhydrite facies and environments, Middle Devonian Elk Point basin, Alberta. Canadian Petroleum Geology Bull., v. 21, pp. 278-343.

Belyea, H.R. 1971. Middle Devonian tectonic history of the Tathalina uplift, southern District of MacKenzie and northern Alberta, Canada. Canada Geol. Survey Paper 70-14, 30 p.

Billings, G. K., Kesler, S. E., and Jackson, S.A. 1969. Relation of zinc-rich formation waters, northern Alberta to the Pine Point ore deposit. Econ. Geol. v. 64, pp. 385-391.

Brock, T. D. 1967. Life at High Temperatures. Science, v. 158, pp. 1012-1019.

Campbell, N. 1957. Stratigraphy and structure of Pine Point area. N.W.T.: Commonwealth Mining Metall. Cong., 6th, Canada, v.2, pp. 87-96.

___________ 1966. The lead-zinc deposits of Pine Point. Canadian Mining Metall. Bull., v. 59, pp. 953-960.

____________1967. Tectonics, reefs, and stratiform lead-zinc deposits of the Pine Point area, Canada: Econ. Geol. Mon. 3, pp. 59-70.

Carter, K.M. 1983. Geology of the N81 Deposit, Pine Point, N.W.T., Pine Point Mines Ltd., unpublished report.

Evans, T. L., Campbell, F.A. and Krouse, H.R., 1968. A Reconnaisance Study of Some Western Canadian Lead-Zinc Deposits. Canada: Econ. Geol., v. 63, pp. 349-359.

Folinsbee, R.E., Krouse, H.R., and Sasaki, A. 1966. Sulfur isotopes and the Pine Point Lead-Zinc Deposits, N.W.T. Canada; (Abstract) Econ. Geol., v. 61, pp. 1307-1308.

Fritz, P. 1969. The Oxygen and Carbon Isotopic Composition of Carbonates from the Pine Point Lead-Zinc Ore Deposits. Econ. Geol., v. 64, pp. 733-742.

Fritz, P. and Jackson, S.A. 1972. Geochemical and isotopic characteristics of Middle Devonian dolomites from Pine Point, northern Canada. Internat. Geol. Cong., 24th, Montreal, 1972, Proc. Sec. 6, pp. 230-243.

Gize, A.P., and Barnes, H. L. 1987. The Organic Geochemistry of Two Mississippi Valley-Type Lead-Zinc Deposits. Econ. Geol., v.82, pp. 457-470.

Grayston, L.D., Sherwin, D.F., and Allen, J.F. 1964. Middle Devonian in McGrossan, R.G., and Glaister, R.P., eds., Geological history of western Canada, Calgary, Alberta Soc. Petroleum Geologists, pp. 49-59.

Haynes, F.M. and Kesler, S.E. 1987. Chemical Evolution of Brines during Mississippi Valley-type Mineralization: Evidence from East Tennessee and Pine Point. Econ. Geol., v.82, pp. 53-71.

Hitchon, B. 1980. Some economic aspects of water-rock interaction. Am. Assoc. Petroleum Geologists, Studies in Geology, No. 10, pp. 109-119.

Jackson, S.A., and Beales, F.W. 1967. An aspect of sedimentary basin evolution: The concentration of Mississippi Valley-type ores during late stages of diagenesis. Canadian Petroleum Geology Bull., v.15, pp. 383-433.

Krebs, W. and Macqueen, R.W. 1984. Sequence of Diagenetic and Mineralization Events, Pine Point Lead-Zinc Property, N.W.T., Canada. CSPG Bull., v.32, pp. 434-464.

Krouse, H.R. and Ueda, A. 1987. Contents and sulphur isotope composition of trace sulphate and sulphide in various rock types. Applied Geochemistry, v.2, pp. 127-131.

Machel, H.G. 1987. Saddle dolomite as a by-product of chemical compaction and thermochemical sulfate reduction. Geology, v.15, pp. 936-940.

Macqueen, R.W. and Powell, T.G. 1983. Organic Geochemistry of the Pine Point Lead-Zinc Ore Field and Region, N.W.T., Canada. Econ. Geol., v.78, pp. 1-25.

McRea, T.M. 1950. On the isotope chemistry of carbonates and a paleotemperature scale. Jour. Chem. Phys., v.18, no. 6, pp. 849-857.

Noble, E.A. 1963. Formation of Ore Deposits by Water of Compaction. Econ. Geol., v.58, pp. 1145-1156.

Ohmoto, H. and Rye, R. 1979. Isotopes of Sulphur and Carbon in Geochemistry of Hydrothermal Ore Deposits, H.L. Barnes, ed. 2nd., JW&S, New York, pp. 509-561.

Powell, G.T. and Macqueen, R. 1984. Precipitation of Sulfide Ores and Organic Matter; Sulfate Reduction at Pine Point, Canada. Science, v. 224, no. 4644, pp. 63-66.

Quinlan, J.F. 1972. Karst related mineral deposits and possible criteria for the recognition of paleokarsts: a review of preservable characteristics of Holocene and older karst terranes. Internat. Geol. Cong., 24th Montreal, Sec. 6, pp. 152-167.

Rasmussen, P. 1981b. Regional stratigraphy and lithology across the barrier complex: Pine Point N.W.T., Pine Point Mines, unpublished report.

Rhodes, D., Lantos, E.A., Lantos, J.A., Webb, R.J., Owens, D.C. 1984. Pine Point Orebodies and Their Relationship to the Stratigraphy, Structure, Dolomitization, and Karstification of the Middle Devonian Barrier Complex. Econ. Geol., v.79, pp. 991-1055.

Roedder, E. 1968. Temperature, salinity, and origin of the ore-forming fluids at Pine Point, Northwest Territories, from studies of fluid inclusions. Econ. Geol. v. 63, pp. 439-450.

Sasaki, A. and Krouse, R. 1969. Sulfur Isotopes and the Pine Point Lead-Zinc Mineralization. Econ. Geol., v.64, pp. 718-730.

Skall, H. 1975a. The paleoenvironment of the Pine Point lead-zinc district. Econ. Geol., pp. 22-45.

Sverjensky, D.A. 1984. Oil Field Brines as Ore-Forming Solutions. Econ. Geol., v.79, pp. 27-37.

Trudingner, P.A., Chambers, L.A. and Smith, J.W. 1986. Low Temperature Sulfate Reduction: Biological Against Abiological. Canadian Journal of Earth Sciences, v.22, pp. 1910-1918.

APPENDIX 1

DRILL-CORE LOGS

NOTE: All logging was recorded in feet to conform with standard Pine Point Mines Ltd. format.

The abbreviation, SRF used throughout these logs stands for subrounded forms. This refers to a distinctive texture seen in Presqu'ile dolomite, and resembles a mass of small egg-shaped nodules.

N81-1

0-70'	Overburden
70-252'	Slave Point Formation
70-112'	O Facies - light grey to tan limestone. Variable texture, micritic to laminated, wispy argillaceous partings, nodular/intraclastic intervals and local flazer bedding.
112-135'	N Facies.
112-130'	Dark-brown, argillaceous limestone. Weakly bedded to blotchy.
130-135'	Dolostone, blotchy, brown to grey, micritic, brecciated - fragment supported.
135-400'	Collapse. Very well mineralized, totally replaced by galena, sphalerite FeS_2 and calcite. Botryoidal sphalerite varies from creamy-yellow to very dark brown. Galena occurs as euhedral crystals: fine masses apparently replacing internal sediments and interbedded with colloform sphalerite layers as well as dendritic masses.
135-225'	Massive sulphides, no host rock visible.
225-252'	Angular clasts of original rocks supported by sulphide matrix. Clasts <10% of total interval. Includes clasts of typical N Facies to about 247'.
237-252'	M1 (Amco shale) clasts replaced by iron sulphides.
252-258'	Large clasts of well preserved M3 (lower Amco) containing bulbous stromatoporoids up to 2" and other fossil detritus.

252-313'	Watt Mountain Formation - Collapsed/brecciated assortment of Watt Mountain lithologies. Sulphide minerals occur as matrix and frature-fill, constituting about 5% of the rock.
313-365'	Sulphide matrix supporting clasts of severely Presqu'ilized, bioclastic dolostone, coarsely crystalline, blue-grey and white. Also clasts of bedded, sandy internal sediments.
365-400'	Muskeg Formation lithologies in clasts, very sandy, loosely-consolidated dolarenite and some dense blue-grey dolmicrite.
313-400'	Sulphide mineralization limited to fractures in breccia (<4%) and some locally disseminated sulphides in Sulphur Point clasts and as replacement in internal sediments.
400'	End of Hole.

N81-13

0-75'	Overburden.
75-183'	Slave Point formation.
75-120'	O Facies - brown, argillaceous limestone; nodular, intraclastic intervals and rip-up clasts, wispy argillaceous partings
96-98'	P bed - similar to above, floatstone with onclolitic stromatoporoid fragments.
124-164'	N Facies - grey to brown argillaceous dolostone; micritic to evenly laminated, blotchy colouration locally. Fenestral "moth-eaten" vuggy porosity. Perhaps gypsum has been removed and is now partially replaced by calcite and native sulphur.
164-168'	M2 (upper Amco) - brown, sandy dolostone, variable, uneven colouration, burrowed, bioturbated character, dolspar partly filling burrows and minor bitumen.
168-179'	M1 (Amco shale) - grey-green, marl.
179-183'	M3 (lower Amco) - grey-brown, argillaceous dolostone containing fossil debris. 181-183 laminated with a more sandy character.
183-232'	Watt Mountain Formation
183-198'	Dolostone (calcareous) light cream to grey colour - some blotchy mottled character in the light-coloured intervals.
198-201'	Cream to grey micritic limestone, contacts show argillaceous intraclastic beds.

211-216'	Dolostone, blotchy, grey-green colour with intervals of gritty, sucrosic, recrystallized dolostone and seams of green clay.
216-480'	Presqu'ile dolostone.
216-238'	This appears to be the top of the karst breccia, (or else it is at 232'). Brecciated, sucrosic dolostone with a variable brown colour. Crackle-breccia, cemented by coarsely-crystalline calcite. Mineralization - occasional euhedral, disseminated galena crystals and galena in fractures associated with calcite. At 238' marcasite becomes very prominent, locally massive and appears to be replacing internal sediments.
238-265'	Breccia and granular internal sediments. Loosely consolidated and very marcasitic. Small amount of white dolspar veining. Scattered regions of disseminated sphalerite and galena. Marcasite obscures these.
265-289'	More of the original Sulphur Point material appears to be preserved here but core is similar to above with prominent marcasite and bedded internal sediments. Remaining Sulphur Point rock is very coarsely recrystallized, blue-grey in colour with white calspar/ dolspar replacement. Original texture obliterated. Occasional galena crystal in calcite veins.
289-300'	Sulphur Point Formation replaced by 40-60% white dolspar and calspar. Large, poorly-formed SRF's. No visible sulphide mineralization.
330-345'	Similar to above with intervals of close-packed, well-formed SRF's; overall blue-grey with white spar veining, iron sulphides and internal sediments.

345-357'	As above, coarse-grained, severely-recrystallized Sulphur Point Formation with abundant disseminated euhedral galena and sphalerite.
257-363'	Coarse-grained galena and sphalerite, in association with coarse, white calspar.
363-384'	Muskeg Formation - tan to beige coarsely crystalline, very sucrosic, uniform dolostone - upper 20' occasionally mineralized large calspar veins.
384-445'	Bioclastic dolostone; severely Presqu'ilized, light creamy-beige, locally faintly laminated. Bioclastic debris becomes more identifiable at deeper levels. Gradually more sandy and more brown in colour at deeper levels. Appears to be grading into D1 Facies of Pine Point Formation. Mineralization - very low grade, disseminated euhedral sphalerite and galena.
424-425'	Stachyodes gravel bed.
445-500'	Pine Point Formation
445-465'	D1 Facies (D3 alteration) - brecciated, fragmental bioclastic, blue-grey to light-brown, dolspar veining <10%, minor disseminated sphalerite.
465-480'	E Facies (D3 alteration) - fragmental dolarenite, sucrosic, cemented by white dolspar (about 10%) and some blue-grey dolspar, minor disseminated galena and sphalerite.
480-500'	E Facies - sandy, light-brown dolarenite, uniform sucrosic character, pin-point porosity and trace amounts of disseminated sulphides.
500'	End of Hole.

N81-19

0-75'	Overburden.
75-173'	Slave Point Formation.
74-140'	O Facies - limestone, medium-brown to light-grey, fine-grained sandy to micritic limestone, very wispy, argillaceous laminations become locally blotchy.
140-173'	N Facies - limestone, medium-brown to grey, finely crystalline to micritic, blotchy to sub-parallel laminations.
173-185'	M2 (upper Amco) - dark-brown dolostone, blotchy character with large stromatoporoid fragments locally.
185-194'	M1 (Amco shale) - dark-grey, fissile marl, very uniform and featureless.
194-196'	M3 (lower Amco) - brown dolostone.
196-220'	Watt Mountain Formation, argillaceous dolostone, veined by white dolspar.
220-357'	Collapse
220-280'	Watt Mountain lithologies, clasts with coarse-grained sandy internal sediments, large Watt Mountain clasts, dolostone and limestone, frequent blebs of green clay, sparry calcite fracture-filling.
280-455'	Top of Presqu'ile alteration.
280-315'	Coarse-grained, locally bedded internal sediments, well recrystallized and veined with calcite.

	Mineralization - 305-315' scattered, disseminated marcasite.
315-357'	Internal sediments, very well Presqu'ilized, mottled blue-grey character. Calcite-flooded (about 40% calcite).
357-455'	Sulphur Point Formation - cream to dark-grey dolostone, coarsely crystalline to micritic.
357-366'	Mottled blue-grey dolostone, calcite-flooded.
366-370'	Cream to blue-grey rhombic dolostone.
370-377'	Blue-grey to cream, upper portion fragmental, lower portion very coarsely recrystallized but appears bioclastic.
	Mineralization - 366-377 sphalerite and galena, interstitially and in fracture; sphalerite about 2% and galena about 1 ‰.
374-384'	Cream dolostone, weakly developed small SRF's, very uniform.
385-400'	C Horizon (Muskeg Formation) sandy, light-brown dolostone and medium-brown laminated dolostone.
393-395'	Calcite-flooded.
400-455'	Sulphur Point continued; mostly blue-grey bioclastic dolostone strongly Presqu'ilized and heavily calcite-flooded. Intervals of SRF texture. Scattered, disseminated galena and sphalerite less than 2% combined.
455-500'	Pine Point Formation

455-485'	D1 Facies - light-brown to beige, sandy, medium crystalline dolostone, fragmental, cemented by calcite. Fossiliferous, containing amphipora, corals and stachyodes. Becomes increasingly fragmental toward lower contact.
485-500'	E Facies - dolarenite, light-brown, uniform featureless character.
500'	End of Hole.

N81-24

0-70'	Overburden
70-177'	Slave Point Formation
70-122'	O Facies - limestone, variable argillaceous content with wispy argillaceous laminae, local rip-up/intraclastic beds.
103-108	P beds - calcareous mudstone matrix with bulbous oncolitic stromatoporoids, brachiopods and rip-up clasts.
122-156'	N Facies - argillaceous dolostone, prominent texture is distinct planar laminae and mottled reduction blotching. Also local intraclastic horizons. Generally darker brown and less intraclastic than O Facies above.
156-163'	M2 (upper Amco) - dark-brown argillaceous limestone, churned-up bioturbated character. Lower 3' intraclastic and fossiliferous.
163-174'	M1 (Amco shale) - dark grey-green marl. Mottled burrowed character.
174-177'	M3 (lower Amco) - dark-brown dolostone, floatstone, oncolitic bulbous stromatoporoids (mostly replaced by white calspar) also small coral and brachiopod fragments.
177-219'	Watt Mountain Formation
177-194'	Blotchy, finely crystalline dolostone, medium-grey reduction mottling.
194-196'	Gritty, argillaceous, calcareous, intraclastic interval.

196-205'	Micrite, upper 6" limestone and the remainder is dolostone. Light-grey, weakly-laminated and stylolitic, locally intraclastic.
205-215'	Mixed interval of green, argillaceous rock, micritic limestone/dolostone locally calcite-filled fractures and minor recrystallization of loosely-consolidated, coarse-grained argillaceous intervals.
215-218'	Light-brown, slightly sandy textured dolostone with dark argillaceous wisps.
218-219'	Bright green, loosely-consolidated silty clay.
219-411'	Sulphur Point Formation
219-225'	Rubble zone (erosional unconformity) Sulphur Point fragments, green clay infilling fractures and vugs.
219-248'	Mostly limestone, weakly Presqu'ilized.
242-245'	Bioclastic rudstone/floatstone. Very light coloured limestone with an abundance of fossil debris, local wackestone intervals. Fine disseminated bitumen gives dark grey colour at 239-248'. Algal laminated interval at 225-234', weakly laminated with fine fenestral porosity (filled by green clay).
248-318'	Bioclastic, strongly Presqu'ilized, locally blue-grey after marcasite. Very coarse intergranular and vuggy porosity, fossil moldic in many cases. Local intervals of large poorly developed SRF's.
318-334'	Possible karst channel, about 15-20% white calspar/dolspar replacement with brown argillaceous component segregated into weak SRF texture and weakly-laminated textures.

326-344'	Internal sediments, coarse, granular, in places finely-bedded, all recrystalllized. About 2% white calspar-dolspar replacement.
351-404'	J (Muskeg Formation) package, generally the interval is made up of darker, denser and less fossiliferous rocks than the Sulphur Point section. The lithologies are repetitive and Presqu'ilization intermittent.
404-411'	Bioclastic dolostone, variably Presqu'ilized blue-grey after marcasite, very dense, similar to D3 but not fragmental.
411-475'	Pine Point Formation.
411-424'	D1 Facies - light brown to tan, very sucrosic dolostone. Intense Presqu'ilization has obliterated most characteristics in the upper section. About 15% calspar/dolspar. Lower 2' quite well perserved as tan dolarenite floatstone with 5% amphipora, coral and stromatoporoid fragments.
424-447'	D1/E Facies - fragmental dolarenite floatstone interbedded with fine-grained, brown, fossil-free dolarenite (E Facies).
447-475'	E Facies - uniform homogeneous, fine-grained dolarenite, light-brown colour.
475'	End of Hole.

N81-27

0-70'	Overburden
70-175'	Slave Point Formation
70-104'	O Facies - brown, argillaceous, limestone with wispy argillaceous laminations, nodular/intraclastic intervals.
86-91'	P bed - bioclastic floatstone, argillaceous limestone with oncolitic, bulbous stromatoporoid fragments (2-6 cm) and other fossil debris.
104-151'	N Facies - grey to dark brown dolostone and calcareous dolostone, blotchy, reduction-mottled micrite to regularly laminated, argillaceous dolostone.
122-130'	Calcite and native sulphur along bedding.
151-162'	M2 (upper Amco) - brown, sandy dolostone, mottled churned-up character.
162-171'	M1 (Amco shale) - dark grey-green marl, weakly mottled and bioturbated character.
171-175'	M3 (lower Amco) - variable brown, slightly sandy dolostone, highly fossiliferous unit, with numerous oncolitic stromatoporoid fragments and replaced fossil debris.
175-208'	Watt Mountain Formation
175-181'	Dolostone, light-grey with dark-grey reduction mottling, locally weakly laminated.
181-181.5'	Sandy dolostone, coarsely crystalline, loosely consolidated.

181.5-185'	Dark-grey dolostone, uneven colouration, very low porosity.
185-186'	Brown to black, speckled dolostone.
186-192'	Micritic dolostone, very light grey to tan.
192-199'	Dolostone, mixed interval of grey to light brown dolostone, weakly-laminated.
199-201'	Micritic dolostone, light-grey with large black/grey reduction blotches (marcasitic) at 200' small (<2 in) interval of disseminated sulphides (galena, sphalerite and marcasite).
201-203'	Light brown/tan, fine-grained dolarenite, weakly laminated. At 203-211', speckled dark grey-green dolostone.
175-208'	Occassional cal/dolspar-filled pores, vugs and fractures with minor amounts of native sulphur.
208-374'?	Sulphur Point/Karst Breccia - This interval comprises internal sediments ~~and marcasite~~, some Watt Mountain fragments, and a few Sulphur Point fragments.
208-230'	Rubbly eroded character-erosional unconformity. Abundant bright-green shale filling open-spaces.
225-245'	Coarsely recrystallized bioclastic dolostone, minor white dolspar, bitumen speckled and a few grains of marcasite.
245-255'	Rods dropped.

255-325'	Very extensive marcasite replacement of host-rock fragments and internal sediments. Minor amount of white and blue-grey dolspar. Marcasite- replaced internal sediments are also fragmented/brecciated and recemented mostly by dolspar. Locally a few galena crystals associated with the dolspar, also occasional colloform sphalerite in dolspar fracture fillings. Recognizable host-rock fragments include Watt Mountain and Sulphur Point lithologies.
325-329'	Presqu'ilized Sulphur Point, coarsely recrystallized, SRF forms with abundant (20-40%) white dolspar and some calspar. Granular intervals of internal sediments occasionally. Very few grains of galena and sphalerite.
329-355'	Variable SRF texture, grey to blue-grey bituminous residues and abundant dolspar (white).
355-359'	Presqu'ilized dolostone, looks like a bioclastic rock, coarsely crystalline nearly white to grey, fossil-ghosting, local weak SRF developments.
359-362'	SRF texture, small (<0.1 cm.), close-packed.
362-374'	Presqu'ilized bioclastic dolostone, heavily replaced and veined by white dolspar and cream to beige rhombic dolostone with some fossil ghosts. Rather sucrosic texture, well-consolidated.
374-384'	Dolostone, becomes more brown with depth (gradational change to typical J-lithologies). (Muskeg Formation) Dense, weakly-laminated and locally blotchy (KJ3) with very short intervals of dense blue-grey dolostone (J1). Sporadic colloform sphalerite and galena associated with fractures.

384-387'	Medium-brown dolarenite - J3, some local weak laminations of slightly more argillaceous material.
387-435'	Sulphur Point Formation. Well Presqu'ilized bioclastic, cream to very light blue-grey colour.
415-426'	Very dark-grey, laminated (algal?) with dolspar replaced fossil debris. Coarsely recrystallized. At 425' Calspar/dolspar-filled fracture with large (0.25 inch) galena crystals and brown crystalline sphalerite. (Over 2 inch intervals.)
426-431'	Stachyodes gravel bed, dark blue-grey dolostone, mass of fossil debris, stachyodes.
435-475'	Pine Point Formation
435-456'	D1 Facies - light-tan dolarenite with abundant fossil debris replaced by calspar and dolspar. Most of the section is weakly Presqu'ilized and replaced by cal/dolspar. Original texture still discernable.
456-475'	E Facies - light-tan dolarenite, gradational contact to D1 above, slightly sucrosic.
469-475'	D3 Facies - derived from E facies, fragmental (also fossil fragments, stromatoporoids and dense recrystallizated texture).
475'	End of Hole.

N81-3

0-67'	Overburden
67-130'	Slave Point Formation
67-68'	P Facies/P Bed - light-brown, calcareous mudstone with oncolitic, bulbous stromatoporoids.
68-111'	O Facies - light-brown to grey, calcareous mudstone. Variable textures with wispy, anastamosing, argillaceous laminae, intraclastic horizons, flazer bedding and rip-up clasts.
88-90'	P bed - floatstone, calcareous mudstone with oncolitic, stromatoporoid fragments, occasional galena in fine hairline fractures.
101-111'	Calcite-flooded interval. This interval is hard to classify into any given facies. A coarsely-crystalline, white, calcite with prominent inter-crystalline and vuggy porosity. Abundant bitumen gives a blotchy character and laminated character similar to algal fenestral porosity. Locally less porous intervals show a slightly laminated character like "zebra banding". Coarsely crystalline galena occurs throughout this section.
111-130'	N. Facies - argillaceous limestone, intraclastic intervals. Section of N Facies that is preserved above the mineralized/collapsed section is less well-laminated than typical for N Facies.
130-390'	Collapse.

130-225'	Massive sulphides filling karst/collapse. Mineralization textures are highly varied and include very finely crystalline, dense, bedded galena, colloform sphalerite, very distinctly banded with galena intergrowths. Inter-colloform pore-space gives a lacey, or spongy character. Sphalerite colour ranges from dark-brown to amber and pale creamy-yellow. Locally native sulphur is visible infilling colloform sphalerite growths and marcasite occurs occasionally as bladed crystals and more often interbedded with galena bands.
225-368'	Collapse continues - occasional clasts of original formations are preserved here. Mineralization textures are similar to above. Galena content increases relative to other sulphides and crystals are larger. White, coarsely crystalline calspar/dolspar veining, less than 1% with blue-grey selvedges, sphalerite (dark-brown to amber) and galena rims.
At 220'	Watt Mountain micrite - medium-brown weakly laminated/blotchy.
At 225'	Amco shale clast - (first occurrence) Dark green, marcasitic shale. Amco/Watt Mountain clasts recognized to 368'.
368-390'	C Horizon - (Muskeg Formation) dolostone (very poor recovery). 368-382' sandy, light-brown dolarenite, sucrosic texture, quite friable (J3). 385-387'? sandy, medium-brown to dark-brown dolarenite, sucrosic, similar to J3 above but laminated (J2). Throughout the C Horizon small grey-white calcite/dolomite veinlets.
387-395'	Very little core here, what there is, is brecciated. Brown micrite cemented by dark grey dolostone, white calcite and sphalerite mineralization.

390-402'	Creamy beige SRF's with blue grey rims.
390-433'	Karst breccia - fragments of Sulphur Point and likely Muskeg Facies rocks, with laminated or varved internal sediments. All are fractured and veined with white and blue grey calcite/dolomite. Presqu'ilization affected the whole section. Sulphur Point lithologies are the most severely altered, to SRF's in the lower 3'.
433-445'	D2 Facies - poor recovery (<20%). Boundstone, cream to grey. Stachyodes gravel with dark-grey marcasitic rims. Also light-coloured euhedral, disseminated sphalerite, and disseminated galena.
445-505'	Pine Point Formation
445-479'	D1 Facies - light-brown to grey, sucrosic dolarenite, fossiliferous (fragmental) floatstone, also brecciated. Fossils include tabular corals, brachiopods and unidentifiable debris. Fractures are filled with white and blue-grey calcite/dolspar fine galena and sphalerite.
479-400'	E Facies - medium-brown sucrosic dolarenite, very uniform homogeneous, fine fractures contain traces of galena.
505'	End of Hole.

N81-31A

0-44'	Overburden
44-196'	Slave Point Formation
44-107'	O Facies - Medium-brown, calcareous mudstone, variably intraclastic to wispy argillaceous partings. Fossiliferous with small, thin-shelled brachiopods.
55-57' 95-8'	P Beds - Bioclastic floatstone with bulbous stromatoporoids with oncolitic coatings, amphipora and brachiopods.
98-138'	Collapse Breccia - Upper section comprises broken and rotated clasts of N facies. Core is poorly recovered. N clasts (104-166') include brown to dark-grey, mottled limestone, clasts are cemented by calcite which is very vuggy and bituminous.
125-127'	Dark-green, unconsolidated clay (internal sediment).
114-138'	Calcite-flooded.
166-179'	M2 (upper Amco) - Dark-brown dolostone, mottled, bioturbated character, local finely intraclastic intervals.
179-193'	M1 (Amco shale) - Dark green, marl. Very small traces of galena in calcite-filled fractures. About 1% calcite-filled fractures and vugs. Occasional blue-grey dolspar margins.
193-196'	M3 (lower Amco) - Grey-brown, dolomitic floatstone with oncolitic, bulbous stromatoporoids.
196-243'	Watt Mountain Formation - Brecciated contact. Watt Mountain section brecciated, cemented by white calcite. Clasts are slightly rotated but little displacement.

196-241'	Blue-grey, blotchy, mottled dolostone.
241-225'	Gritty, intraclastic horizons.
235-260'	Rubble Zone - Erosional unconformity including, clasts of silty dolostone and green Watt Mountain claystone.
243-410'	Sulphur Point Formation.
243-410'	Presqu'ilized, bioclastic floatstone, grey bituminous dolomite.
243-260'	Breccia with angular clasts (0.5-2.0 inches) cemented by calcite. Minor, green clay component apparently of Watt Mountain origin, also present.
260-327'	Karst breccia interval, about 60% internal sediments - well laminated, coarse, gritty dolomite. Bedding angles at various inclinations. Dark-grey colour.
260-300'	Mineralization - Very prominent FeS_2 associated with internal sediments. Minor traces of galena and sphalerite disseminated and in fractures only to 310'. 310-325' very dark-brown and amber-coloured sphalerite occurs disseminated and on outer edges of calspar veining. Crystal size highly variable - (up to 0.25 inch). Also colliform sphalerite asociated with galena and with calcite.
339-345'	Very uniform, homogeneous, white dolomite. Incipient SRF texture.
345-368'	Highly variable section of interbedded Muskeg Formation dolarenites (J beds). Presqu'ilization is intermittent and variable in intensity.

368-380'	Very light-coloured J Facies strongly Presqu'ilized to an equigranular texture in many intervals.
368-380'	Creamy-blue coloured J bed, blotchy, stylolitic.
380-387'	J Bed, white, homogeneous dolomite, equigranular texture.
387-391'	Intense blue-grey mottling and calspar replacement (about 1%).
391-410'	Light-brown to grey dolomites. Below 400' crackle-breccia - small calcite filled fractures.
410'	End of Hole.

N81-32A

0-32'	Overburden
32-165'	Slave Point Formation
32-106'	O Facies - limestone, light-brown to grey, argillaceous limestone, dark, wispy argillaceous partings. Intraclastic intervals, rip-up clasts and flazer bedding frequent.
45-60' 73-76'	P beds - bioclastic interval of argillaceous limestone with oncolitic stromatoporoids.
106-170'	N Facies.
106-108'	Brown, earthy textured, argillaceous dolostone and 6" interval of semi-consolidated mud.
108-152'	Calcite-cemented collapse breccia, dark-grey to black also with short intervals of loose sandy/gravelly unconsolidated internal sediments. Rock portion of interval comprises angular clasts (generally <2") floating in dark-grey bituminous calcite cement. Clasts are O/N Facies as well as finely-laminated, dark-brown, internal-sediments. A few granite pebbles found here as well.
153-165'	Similar to above, but this breccia consists of larger clasts (blocks up to 3' recognized in the core) and shows more white calcite in fine fractures within the blocks. Internal sediments are also preserved in larger blocks (6" to 15"), finely-bedded and replaced by calcite.

165-170'	M2 (upper Amco) - Contact jumbled by collapse. At 166' few well-formed cubes of galena and traces of very fine, yellow sphalerite. Brown, slightly sandy dolostone, occasional stromatoporoid fragments, dolspar/calspar veining locally shows blue-grey dolspar margins.
170-183'	M1 (Amco shale) - dark-grey, marl impregnated with fine FeS_2 gives a dark-green cast. A 2' interval of loose sand and gravel (internal sediments), as well as short (2') intervals of consolidated, finely-bedded internal sediments. Below 179' angular clasts of M1 are supported by a matrix of internal sediments which have been replaced by white and blue-grey calspar. Clasts are rimmed with calspar.
183-191'	M3 (lower Amco) - argillaceous dolostone, biostromal unit. This interval is very poorly preserved and poorly recovered. The interval is brecciated and supported by a matrix of argillaceous, sandy, internal sediments, fractures are filled with calspar/dolspar which have blue-grey margins.
191-256'	Watt Mountain Formation - continued collapse breccia.
191-209'	Blotchy, micritic dolostone, badly broken-up and infilled with brown, argillaceous material, and loose sand. Some intervals are slightly calcite-flooded. Calcite veining minor.
209-248'	From 210' Watt Mountain lithologies are less disturbed. At 209' and 215' loosely-consolidated gritty intervals containing about 10% green clay. From 220' bitumen becomes increasingly prominent and is associated with white calcite in fractures. At 236' Presqu'ilization begins. 248-256' gritty dolostone and green clay - very loosely consolidated, calcide flooded, very poorly recovered.

256-390'	Sulphur Point Formation - strongly Presqu'ilized, coarse-grained dolostone. Upper 20' very rubbly weathered character (erosional unconformity) Calspar/dolspar veining and replacement dominant.
270-290'	Very high FeS_2. Brecciated, Sulphur Point clasts are replaced by FeS_2 and floating in matrix of very white calspar/dolspar. Below 288', FeS_2 becomes more pervasive and occurs in the calcite cement as well.
290-310'	Massive FeS_2 replacement, probably an interval of internal sediments, locally hints of bedding and traces of galena and sphalerite.
310-336'	Traces of brown sphalerite, fine botryoids in Presqu'ilized internal sediments. Internal sediments are grey, coarse, sucrosic, with some suggestion of bedding preserved.
336-348'	Dolostone; very dense, clean, light-cream colour. Very strongly Presqu'ilized, no trace of original character.
348-360'	C Horizon (Muskeg Formation), extremely dense, blue-grey dolostone.
360-390'	Presqu'ilized Sulphur Point, very coarsely crystalline, beige to blue-grey dolostone. Local suggestion of fossil ghosts and a bioclastic origin.
390-410'	Pine Point Formation - Presqu'ilization and internal sediments persist. Upper 2' looks like D3, fragmental, very dense, blue-grey dolostone cemented by white spar. No visible fossils. Most of the interval is calspar/dolspar replaced.

400-410'	E Facies - uniform beige dolarenite.
410'	End of Hole.

N81-35

0-70'	Overburden
70-250'	Slave Point Formation
70-120'	O Facies - grey-brown, calcareous mudstone, irregular anastamosing argillaceous partings, local intraclastic intervals and a few rip-up clasts. At 97' the first occurence of galena. Very small amount in pore spaces. Poor recovery here but the O/N contact is correct within 5'.
70-74' 89-81	P Beds - light brown limestone, floatstone with bulbous, oncolitic stromatoporoids and amphipora.
120-135'	N Facies - dark, bituminous limestone to light grey limestone. Calcite and bitumen as fracture-filling <1 ‰ Recovery very poor here.
135-375'	Karst/collapse.
135-283'	Collapse - massive galena and sphalerite mineralization. Very little recognizable Slave Point or Watt Mountain. Mineralization - colloform and euhedral sphalerite. Colour ranges from very dark-brown to a very pale-yellow. Galena occurs in massive form, infilling within the colloform sphalerite and as a rim to calcite veins.
216-229'	M2 (upper Amco) - medium-brown dolostone, 2-4% fossils including stomatoporoid fragments and stachyodes.
229-259'	M1 (Amco shale) - massive marcasite, 1-2% calcite veining with minor galena and sphalerite.

250-283'	Watt Mountain Formation - no internal sediments and very little calcite or dolspar, locally massive marcasite. Variable amounts of marcasite with local, coarsely crystalline galena and sphalerite.
283-445'	Sulphur Point Formation - heavily karsted and infilled with galena, sphalerite and FeS_2. Preserved Sulphur Point is Presqu'ilized. Mineralization occurs in calspar and dolspar veins, in cavities and disseminated. Marcasite ocurs intimately with galena and sphalerite.
283-445'	Presqu'ilized dolostone.
375-387'	C Horizon (Muskeg Formation) - dark-brown, sucrosic dolarenite, at lower contact a few amphipora or stachyodes. Lower 5' brecciated and veined with white calcite (crackle-breccia).
283-445'	Presqu'ilized, bioclastic floatstone, cream to blue-grey dolostone, medium to coarsely crystalline. About 5% fossil moldic vugs and fossil ghosts.
435-445'	Dark-grey, finely disseminate marcasite, disseminated galena and amber-coloured sphalerite (<1% PbS + ZnS).
445-475'	Pine Point Formation - D3/D1 Facies, light-brown dolarenite matrix, locally marcasitic, giving a blue-grey colour. Fragmental interval veined by calspar/dolspar. Prominent fossil content (12-15%) includes stachyodes, stromatoporoids, corals?? Trace sulphide in fracture with calcite and dolspar.
475'	End of Hole.

N81-36

0-80'	Overburden
80-372'	Slave Point Formation
80-116'	O Facies - grey-brown argillaceous limestone, irregular, wispy argillaceous laminations, nodular intraclastic intervals. Occasional very small blebs of galena.
116-138'	N Facies - dark grey, argillaceous dolostone, locally laminated to blotchy texture. "Moth-eaten" vuggy character occasionally parallels laminae and looks like evaporite minerals were removed. Occasional calcite infilling associated with bitumen. Lower contact is lost in the collapse. 130-138' galena and sphalerite replacing along bedding laminae and in fracture.
138-240'	Collapse - mineralization - massive sulphide mineralization to about 240' is an intimate mixture of yellow, colloform sphalerite and blebs of finely crystalline galena, replacing Slave Point rocks, internal sediments and filling open-spaces. Very little of the original rock is preserved and only occasional calcite is observed.
240-253'	Continues to be heavily mineralized, but more of the host rock is preserved. Galena and sphalerite and some marcasite occur in fractures and as a matrix for collapsed blocks of host rock, (massive, granular and colloform texture).
253-296'	Fracture-filling galena, sphalerite and some calspar. Locally fine-grained marcasite. Throughout this section the sphalerite is very light-coloured, and mostly colloform. Where euhedral sphalerite is visible it is a light-amber to yellow colour but some brown is seen on outer margins.

138-240'	Collapse.
138-221	Clasts of N Facies.
221-225'	Clasts of Amco (M2) completely obliterated by sulphides, but texture of M2 is preserved.
225-239'	M1 shale remnants, dark green marcasitic shale, almost totally replaced by FeS_2, brecciated and cemented by sulphides and some dolspar. Some clasts are fractured and galena fills fractures. Disseminated and open-space filling textures in sulphides. Brown sphalerite is becoming more prominent at deeper levels.
239-296'	Watt Mountain Formation - variable interval of Watt Mountain lithologies and internal sediments (recrystallized). Sulphides are mostly limited to fracture-fillings and other open-space filling. Euhedral sphalerite becomes increasingly prominent with depth. Sphalerite here is highly variable in colour and texture (creamy-yellow through tan and dark brown).
296-372'	Sulphur Point Formation - from this point down the rocks show bitumen impregnation and recrystallization textures characteristic of the Sulphur Point Formation, and more internal sediments. Sulphide mineralization is less abundant and mostly in association with calspar veining, but some open-space filling sulphides also occur.
360-370'	D3 Facies - creamy-beige, highly fossiliferous dolostone, karsted with small chunks of internal sediments.

365-379'	Internal sediments - brown dolostone, sandy, well laminated and crackle-brecciated. Cemented by white and blue-grey dolspar. Below 355' sulphide mineralization is infrequent, and occurs as vein-filling in association with cal/dolspar.
375-387'	Muskeg Formation (C Horizon) - J3 sandy, brown dolarenite, dense, slightly sucrosic. Probably some karsting and internal sediments here.
387-398'	D2 Facies - coarsely recrystallized dolostone packed with fossil debris.
398-440'	Bioclastic floatstone - strongly recrystallized fossiliferous dolostone, variable grey colour due to bitumen impregnation.
440-445'	Internal sediments - strongly recrystallized and veined with calspar/dolspar.
445-475'	D3 Facies - (After D2 and D1) fragmental blue-grey to tan fossiliferous dolostone, very dense and severely altered but some fossil "ghosts" and few well preserved fossils remain.
475'	End of Hole.

N81-41

Note:	The recovery in this hole is very poor. (<50%) All contacts and footages are approximate.
0-74'	Overburden
74-270'	Slave Point
74 - ??	O Facies - tan to medium-brown calcareous mudstone, wispy, argillaceous partings and intraclastic intervals.
80-83, 85-87'	P beds - stromatoporoid floatstone, mudstone matrix with oncolitic, bulbous stromatoporoids, small, thin-shelled brachiopods and amphipora.
105-116'	Replaced interval - white and dark-grey calcite, mottled to weakly laminated character, approximately 25% bitumen and possibly sulphides, especially very fine grained marcasite.
116-230'	Massive sulphides/Collapse Breccia - this section is completely replaced by galena, sphalerite and iron sulphides. No internal sediments were identified and only rarely, very minor calcite/dolomite replacement in veining. Occasionally host-rock clasts can be recognized.
116-129'	Massive galena, only 1.5' recovered. One fragment shows that sphalerite was present here, closely associated with galena. It appears that the sphalerite has been more friable and prone to grinding by drilling.
120-125'	O Facies - as above, hairline fractures filled with sulphides, (galena?).

125-145'	Very finely crystalline dense sulphide mineralization. Galena and sphalerite are very closely associated with each other. About 1% calcite, filling fractures and disseminated in small pore-spaces. Cellular vuggy porosity is low, (2-5%). Sphalerite in this section is nearly all dark-brown.
145-157'	Transitional change from above to predominantly colloform sphalerite. Colour variation increases markedly from dark-brown through amber to a very light, powdery beige. Galena is present infilling botryoidal sphalerite along with marcasite. Crystal-form varies from euhedral (about 0.4 inch to very fine indistinct grains).
157-183'	N Facies.
157-183'	Transitional change in texture. Botryoids are no longer prominent. Dense bands of finely crystalline galena (0.1 to 0.2 inch) alternate with dense fine-grained, earthy sphalerite bands. These bands are subparallel to wavy and mostly discontinuous. Very minor, white calcite also. Fenestral porosity within sphalerite is about 0.25% and pores are from 0.1 to 0.2 inch approximately.
183-203'	M1 (Amco shale) - breccia of dark-green marcasitic shale clasts. Clasts comprise 5-10% of the total section. Most of the section is coarse granular galena and sphalerite. Galena floating in sphalerite. Galena as 0.1 to 0.2 inch euhedral grains. Sphalerite is dark-brown, earthy form. Galena content is increasing with depth.
203-220'	Sulphide textures similar to 183-203'. This intersection is slightly more earthy, occasionally shale/clay infills fractures. The clay is greenish and looks like it is derived from Watt Mountain Formation.

220-255'	Core missing.
255-315'	Collapse breccia - This interval is made up of Slave Point, Amco shale, and Watt Mountain clasts and internal sediments plus sulphides. Clasts are fractured and fragments are rotated. Banded or varved internal sediments first occur at 257'. All clasts are dolostone. Very occasionally white calcite occurs as fracture-filling to 305' then increased with depth to around 3-4%.
255-275'	Mineralization - in fractures and between clasts. Textures in the breccia vary, including very light-beige, powdery botryoidal sphalerite with galena rims. This seems to be associated with replaced internal sediments. Unmineralized clasts are seen floating in this fine-grained mineralization. Euhedral sphalerite is rare, occurs in vugs and pore-spaces.
275-300'	Grade of mineralization drops abruptly. Mineralization almost all limited to fractures. Euhedral sphalerite becomes more common but still <1% of sphalerite mineralization. At 293' very fine-grained brown sphalerite appears to be disseminating from fractures and possibly replacing very fine internal sediments (puzzling texture). From 290' large coarsely crystalline sphalerite veins become prominent. Core recovery is very bad, cannot give percentage of total rock. This point is probably the upper limit of the tabular karst-aquifer horizon and also likely near the elevation of the Watt Mountain/Sulphur Point erosional unconformity.
315-325'	Massive marcasite and white calcite veins. At 323' bedded internal sediments are brecciated and cemented with calcite. Galena, sphalerite and iron sulphides are all associated with calcite here. Appears that marcasite may be replacing internal sediments of the weathered rubble zone of the unconformity.

325-390'	Less than 10% core recovery. Appears that this unit was originally Presqu'ilized Sulphur Point, now very strongly altered to coarsely crystalline dolostone, coloured dark-grey by fine sulphide impregnation. Locally there are hints of granual internal sediments but this is the most poorly-recovered material. Coarse dogtooth dolspar/calspar crystals locally.
365-390'	Coarse granular dolarenite, no bedding, may have been internal sediments or possible J3 (Muskeg Formation).
390-395'	Consolidated sandy, light-brown dolarenite. Uniform, homogeneous character with pin-point porosity.
325-395'	Mineralization is mostly fracture-hosted, colloform sphalerite with a wide range of colours, amber to dark-brown. Galena is more granular in form.
395'	End of Hole.

N81-47

0-82'	Overburden
82-201'	Slave Point Formation
82-141'	O Facies - light-brown to tan, fine-grained dolostone, fine wispy laminations, largely intraclastic with an abundance of rip-up clasts and nodules. At 85-86' P bed no amphipora marker bed recovered.
141-174'	N Facies - calcareous dolostone and dolostone, regular aminations to blotchy textures. Brown to dark-grey and blue-grey. White calcite and native sulphur infilling cavities, along bedding and in fractures, from 146-160' (160-170' occasional native sulphur).
174-186'	M2 (upper Amco) - dark-brown, intraclastic, nodular dolostone, small amount of calcite in fine fractures and small cavities. Lower portion has churned-up character.
186-196'	M1 (Amco shale) - grey-green marl.
196-201'	M3 (lower Amco) - dark-brown, fossiliferous dolostone, stromatoporoid fragments replaced by white calcite in the upper 2.5 feet. Below this mottled, intraclastic character, possibly bioturbated.
201-241'	Watt Mountain Formation - limestone and dolostone, variable grey to brown, fine-grained, texture variable; locally laminated, or blotchy micrite and intraclastic, gritty character.
271-???'	Sulphur Point Formation.
241-475'	Presqu'ile dolostone.

241-260'	Crystalline dolostone, heavily replaced and recrystallized. Very porous. Cream to light-grey colour. Bitumen filling pore spaces. Very minor galena at 254' over 1 foot only.
260-350'	60% white dolspar replacement, white to blue-grey, local fossil "ghosting" (gastropods??), a few small occurences of native sulphur. Weakly developed SRF texture. Some rimmed with brown, bituminous residue; local coarse-bladed calcite filling vugs. 284-285' laminated (algal??).
340-434'	Internal sediments - brown, weakly laminated floating in white dolspar replacement. Medium sandy texture. From 343' SRF texture continues, becoming prominently blue-grey, small, well-developed and close-packed.
350-356'	Internal sediments - sandy, gritty, locally unconsolidated.
370-375'	Internal sediments - similar to above but heavily marcasite-impregnated from 371-372'.
375-385'	Equigranular dolostone, light-grey to cream, coarse crystalline, minor disseminated galena and sphalerite in fine fractures.
385-397'	C Horizon (Muskeg Facies) - mostly brown, dense, fine dolarenite, minor dolspar replacement and trace galena and sphalerite in fractures. 395-397' finely disseminated galena and sphalerite.
391-435'	Coarse-grained, recrystallized dolostone, creamy blue-grey, dense, equigranular, local disseminated galena and sphalerite.
435-475'	Pine Point Formation.

435-455'	D3 Facies - dense blue-grey fossiliferous dolostone, fragmental rock, cemented by white dolspar, fossil debris (stromatoporoids recognized) and minor disseminated sphalerite.
455-475'	D1 Facies - calcite-flooded sucrosic texture, similar to E facies, brown colour, lower 10 feet fossil ghosts.
475'	End of Hole.

N81-50

0-74'	Overburden
74-185'	Slave Point Formation
74-130'	O Facies - brown, argillaceous limestone, variable textures, intraclastic/nodular beds, flazer texture and wispy, argillaceous laminations.
130-159'	N Facies - dark-brown, argillaceous dolostone, mottled grey-brown micritic dolostone and dark-grey, bitumen speckled dolostone, most prominent textures are distinct, parallel laminations.
158-171'	M2 (upper Amco) - dark brown, argillaceous/bituminous dolostone, bioturbated appearance. Intergranular and fracture-filling white calcite.
171-181'	M1 (Amco shale) - dark grey-green marl.
181-185'	M3 (lower Amco) - dark brown argillaceous dolostone with mottled, bioturbated character, fossil debris (about 10%) comprising oncolitic stromatoporoid fragments, brachiopods and other detritus; all fossil detritus is calcite replaced.
185-227'	Watt Mountain Formation - dolostone, calcareous dolostone and shaley dolostone, grey to brown with some green shaley intervals.
181-207'	Mottled, fine-grained dolostone, grey-green with darker reduction mottling.
207-212'	Argillaceous silty dolostone, grey, gritty textured.
212-215'	Grey, micritic dolostone, few hairline fractures with calcite and FeS_2 fillings.

215-219	Mixed interval of fine-grained, grey, micritic dolostone, grey-green with dark-grey, silty horizons. Local "moth-eaten" vuggy porosity filled by calcite and native sulphur, looks like replaced evaporite crystals.
219-227'	Limestone, grey to grey-green micritic, with minor calcite and native sulphur in vugs.
227-435'	Sulphur Point Formation
227-274'	Erosional unconformity - rubbly, decomposed dolostone and grey-green shale. Bitumen is very prominent from 245-260. Crackle-breccia cemented by bitumen. Less bituminous intervals are well Presqu'ilized with weak SRF develpment. Blue-grey colour after finely disseminated iron sulphides.
274-370'	Dolostone - variable colour, light-beige to light grey-blue. Immediately beneath the rubble zone is a very dense, cream-coloured micritic dolostone.
(274-277')	Below this the section consists of coarsely crystalline dolostone, prominently rippled with white dolspar. Insoluble residues are segrated, giving a brown rippled effect and brown rims to SRF's. It appears that this section originated as a bioclastic rock.
320-326'	Blue-grey, laminated dolostone, suggests algal character, also Presqu'ilized.
326-336'	Blue-grey dolostone, SRF texture, mass of small, well formed loosely packed SRF's.
336-328"	Severely Presqu'ilized and dolspar replaced, with brown, insoluble residues, bedded appearance (internal sediments?).

338-351'	Blue-grey to tan dolostone, bioclastic "ghosts" and fossil moldic vugs. From 345 becomes extensively dolspar replaced 350-351 stachyodes gravel bed.
370-384'	C Horizon (Muskeg Formation) - brown argillaceous dolostone, weakly Presqu'ilized and dolspar replaced, much more dense than Sulphur Point Formation. 370-374? mineralized, disseminated galena and dark-brown, euhedral sphalerite.
384-435'	Sulphur Point Formation continues - sandy, beige, rhombic dolostone with short (1') intervals of laminated blue-grey (algal??)dolostone. Mineralization - galena and sphalerite lining vugs and filling fractures. 415-430 disseminated light-yellow to brown sphalerite and galena as fracture filling.
435-475'	Pine Point Formation.
435-465'	D3-D1 Facies - weakly Presqu'ilized, calspar/dolspar fracture filling (white and blue-grey) fragmental rock from 460.
465-475'	D3/E Facies - fragmented, fine dolarenite, more sandy than above; very slightly Presqu'ilized, but dolspar more abundant (and more blue-grey) at deeper levels.
475'	End of Hole.

N81-55

0-80'	Overburden
80-140'	O Facies - light brown, argillaceous dolostone, common wavy argillaceous partings and nodular/ripped-up intervals.
87-91' 120-123'	P beds - upper section; oncolitic stromatoporoid fragments, (up to 2.5 in) in silty dolostone matrix. Lower section; similar matrix but stromatoporoids not seen but other fossil debris present.
140-165'	N Facies - brown, argillaceous dolostone, upper 10' quite intraclastic and nodular becoming more uniformly parallel laminated with depth. At 144 first signs of replacement/alteration with calcite filling along fractures, bedding planes and interstitially.
165-375'	Karst/breccia interval.
165-183'	M2 (upper Amco) - massive sulphides begin. Replacement of mottled, silty dolostone by sulphides. Galena and sphalerite are fine-grained and disseminated interstitially, slightly coarser crystals fill fractures. Most replaced rock is quite dense, but locally the coloform masses of sphalerite show a "lacey" open work texture. NOTE: long interval for M2; either collapsed and infilled with internal sediments or the N/M contact is incorrectly located.
183-218'	M1 (Amco shale) - grey-green marl, typical dark colour, crackle-breccia intervals cemented by sphalerite and galena and massive sphalerite and galena as open-space fillings. M1 clasts are not replaced by marcasite but show a coating or margin of fne-grained iron sulphides. Below 195' calcite infilling of pores and large fractures becomes more prevalent.

218-230'	M3 (lower Amco) - very poorly recovered and almost entirely sulphides. Very fine-grained yellow to light-brown, powdery, colloform sphalerite, distinctive "lacey" or fenestral character. Not much calcite. Small interval of brown, silty dolostone, somewhat intraclastic with a few thin-shelled brachiopod fragments.
230-340'	Watt Mountain Formation.
230-295'	Brecciated/collapsed mixture of Watt Mountain fragments, prominent white calspar/dolspar veining and cementation of clasts. Relatively coarse-grained galena, well formed cubes, most prevalent sulphide. Sphalerite is not abundant and is very fine-grained and powdery.
295-297'	Watt Mountain component more fully preserved, sphalerite dominant sulphide, fine-grained, appears to be replacing original rock grain by grain. Minor galena filling small vugs.
297-315'	Mostly micritic Watt Mountain lithologies. Dark grey FeS_2 nodules or reduction blebs.
315-340'	Few dark grey silty dolostone clasts but mostly sulphides, including very coarse (0.5" - 1.0"), well-formed galena cubes to about 325. Below this, much finer-grained. Sphalerite most abundant, yellow through brown to black, finely banded botryoids and powdery-fine disseminated grains. Few calspar/dolspar veins and pore fillings.
340-435'	Sulphur Point Formation (Watt Mountain/Sulphur Point contact unknown - only massive sulphides no host-rock remains).

340-360'	Presqu'ilized, coarse rhombic-textured dolostone, white to blue-grey, almost entirely sulphides here too. Colloform sphalerite filling fractures with galena intimately embedded in the botryoids, coarse-grained galena cubes are well-formed, fine disseminated sphalerite locally disseminated from fractures into clasts.
360-383'	Totally recrystallized white dolostone, rhombic texture. Prequ'ilization has compoletely obliterated original features. At 375 approximate base of karst dissolution channel.
383-395'	C Horizon (Muskeg Formation).
383-385'	J3 - sandy, brown, weakly-bedded dolarenite
385-390	Presqu'ilized J Facies - brown and white calspar/dolspar replacement (probably KJ3).
390-395'	White and blue-grey dolspar veining and replacement.
395-435'	Sulphur Point Formation - Presqu'ilized, bioclastic floatstone and rhombic dolostone. Colour variation white to blue-grey to light tan. Locally galena and possibly some fine-grained sphalerite in small vugs above 405.
435'	End of Hole.

N81-56A

0-48'	Overburden
48-233'	Slave Point Formation
48-124'	O Facies - light brown to medium brown, calcareous mudstone, intraclastic and bioclastic with thin-shelled brachiopods and locally some amphipora. Bedding is weakly-laminated and commonly anastamosing with small rip-up clasts.
55-58'	P Bed - as above with oncolitic, bulbous stromatoporoids.
79-432'	Karst - breccia zone, angular, rotated clasts, cemented by white and blue-grey calcite, (clasts are mostly O Facies to 120). Calcite is also brecciated and crackled. Locally the calcite is coarse and vuggy with bitumen in vugs and along hairline fractures. Internal sediments are rare above 120.
90-128'	Collapse - breccia with dark, granular, internal sediments. Calcite veining and cementation between clasts continues. Locally clasts of N Facies are preserved as dark-coloured limestone, well-laminated or blotchy, also coarse, intraclastic horizons occasionally.
124-214'	N Facies.
128-263'	Main mineralized interval. 128-138 crumbly galena badly broken up. It appears that this interval was a very coarsely Presqu'ilized section with very abundant intercrystalline porosity. Bitumen occurs here in pore spaces. 138-145 massive galena with 5-10% sphalerite. 145-160 contains massive sulphide ore at about 3:1 ZnS:PbS. Sphalerite is finely botryoidal and galena appears to be intergrown.

214-224'	M2 (upper Amco) - dolostone, finely crystalline, uneven colouration, about 0.5% small, thin-shelled brachiopods. Disseminated and vug filling, light-yellow sphalerite. Brecciated, (crackled and rotated but no significant displacement of clasts). At 220 some internal sediments and clasts of M1.
220-233'	M1 (Amco shale) - dark-green marl, first occurrence recognized at 220, becomes the major rock type at 224.
NOTE:	No M3 (lower Amco) was recognized in this core.
233-295'	Watt Mountain Formation - variable interval, mostly blotchy micritic, calcareous dolostone and laminated dolostone. Remnants of green clay, brecciated intervals and also some N Facies-like clasts. Bedding angles are highly variable. Much of the core has been weathered to a unconsolidated mass of clay and silt. Disseminated sphalerite and galena are seen in the Watt Mountain Facies clasts and also in fractures, both with and without calcite.
288-427'	Karst - breccia, with 10-20% banded or layered internal sediments. Grey dolostone, veined and replaced by white and blue-grey dolspar. At 380-397 a few occurrences of Watt Mountain Formation green clay. Mostly a grey, Presqu'ilized, bioclastic dolostone. Few occurrences of sphalerite and galena, very low grade, fracture hosted.
427-440'	Pine Point Formation.
427-432'	Dark-brown, laminated dolostone (internal sediments), brecciated, rotated clasts cemented by white calspar.
432-440'	D3/D1 Facies - dense, dolarenite floatstone, brecciated, locally blue-grey marcasite impregnation.
440'	End of Hole.

N81-65

0-86'	Overburden
86-180'	Slave Point Formation
86-120'	O Facies - light-brown to grey, calcareous mudstone. Highly intraclastic interval, bedded sections show irregular anastamosing laminations, few rip-up clasts and flazer structures.
120-156'	N Facies - dark-grey dolostone, parallel-bedding, finely-laminated character dominant with blue-grey reduction mottled intervals. Very rare calcite replacement along bedding.
156-170'	M2 (upper Amco) - medium-brown dolostone. Uneven churned-up character, probably bioturbated. Few brachiopods.
170-179'	M1 (Amco shale) - dark grey-green marl. Very rare fossil moldic vugs, probably after brachiopods.
179-184'	M3 (lower Amco) - dark-grey dolostone. Blotchy, bioturbated interval M1/M3 contact approximately 6" intraclastic/fossiliferous horizon. Small brachiopods comprise about 2% here. M3 top appears scoured or ripped-up. One oncolitic, bulbous stromatoporoid preserved at 180.
180-230'	Watt Mountain Formation

180-201'	Blotchy dolostone, upper 3' dark grey, laminated, locally intraclastic and bitumen impregnated. Remainder of interval light grey-blue with darker reduction mottling. At 187-189, a gritty intraclastic interval, dolomitic with some calcite replacement and native sulphur along bedding. At 189 darker more argillaceous band with about 1% amphipora.
201-230'	Mixed interval of blotchy, dense dolostones and gritty, argillaceous intervals. At 208, dark-green clay (about 6").
230-364'	Karst channel.
230-244'	Replaced interval - about 60% coarse crystalline calcite and granular, recrystallized internal sediments.
230-430'	Sulphur Point Formation - entire section is very strongly Presqu'ilized, no sign of the original rock remains between 230-270. Below 277 very coarse, vuggy porosity appears to be fossil-moldic in origin. Vugs are lined with coarse-crystalline white dolspar. Trace marcasite/pyrite(?) occasionally in vug lining. Incipient SRF texture above 300. Below this SRF's are well-developed.
364-393'	C Horizon (Muskeg Formation) - dolostone, dense, blue-grey and tan, from 364-370 crackled and cemented with calcite.
393-413'	D2 Facies - cream-coloured dolostone, strongly Presqu'ilized to an equigranular texture, locally porosity and vuggy character suggest fossil moldic origins after stromatoporoids.

413-430'	C Horizon (Muskeg Formation) - very dense dolostone, not Presqu'ilized. Weakly-laminated to blotchy character. At 425 amphipora gravel bed. Poor core recovery here (425-430 only 6" recovered).
430-475'	Pine Point Formation.
430-465'	D1 Facies - light-brown, dense, dolostone matrix, floatstone with 4-10% fossil fragments including corals, stromatoporoids and amphipora. Upper 2.5' very poorly recovered (<305). This interval appears slightly brecciated (<.25%) calspar cement in fractures.
465-475'	E Facies - light-brown, dolarenite. Homogenous, very clean, featureless character.
475'	End of Hole.

N81-67

0-92'	Overburden
92-210'	Slave Point Formation
92-150'	O Facies - limestone, light-brown argillaceous, rip-up clasts and flazer bedding.
150-183'	N facies - mostly dolostone, some calcareous dolostone and limestone. Dark-brown to grey colour. Well-defined, regularly laminated intervals and blotchy micritic intervals.
183-194'	M2 (upper Amco) - dolostone, brown argillaceous, mottled, bioturbated character, small amount of fine fossil debris replaced by calcite.
194-205'	M1 (Amoc shale) - grey-green marl, very uniform.
205-210'	(Lower Amco) - argillaceous limestone, dark-brown, slightly fossiliferous.
210-252'	Watt Mountain Formation - mixed interval of calcareous dolostone and shaley dolostone, gritty sucrosic to micritic textures, locally recrystallized.
252-395'	Sulphur Point Formation - very severely Presqu'ilized, bioclastic dolostone, light-cream to blue-grey colour. Variable textures include SRF's, and laminated character, prominent white vein dolospar (up to 30%) and prominent bitumen staining. Occasional native sulphur filling vugs.
360-???'	Karst channel - sandy sucrosic internal sediments, prominent white vein dolomite throughout.

487-495'	Massive sulphide replacement consisting of colloform sphalerite, disseminated sphalerite and galena crystals. Sphalerite is mostly light-yellow grading to dark brown.
495'	End of Hole.

N81-69

0-82'	Overburden
82-239'	Slave Point Formation
82-175'	O Facies - brown, slightly argillaceous, micritic limestone, nodular intraclastic horizons and some flazer bedding and wispy argillaceous partings, fine, sporadic occurences of galena in pore spaces.
82-95' 108-113'	Silty limestone - floatstone, fossil debris includes oncolitic stromatoporoids and brachiopods.
119-126'	Silty dolostone - grey to brown with nodules of brown micrite, sporadic occurrences of galena continue. At 126 amphipora marker-bed, very dark-brown irregularly laminated dolostone (looks carbonaceous) with amphipora fragments.
130-455'	Karst/collapse breccia.
130-175'	O/N Facies - angular fragments, bedding angles at various orientations, sandy, internal sediments support the breccia and are locally replaced or infilled by fine-grained galena and by dark-brown sphalerite.
175-200'	N Facies - more-or-less extensively replaced by galena and sphalerite. Large botryoids of sphalerite, loosely support well-formed cubic galena crystals. Galena also as dense masses filling open-spaces. Both are disseminating into host-rock clasts. Base of N Facies consists of well-laminated, silty, grey to brown, internal sediments well-consolidated.

200-233'	M1 (Amco shale) - green marl, some marcasite, (along fractures mostly), some disseminated and replacing nodules. Coloform sphalerite and associated galena appear to be filling open space but not seen within the marl itself. Becomes more brecciated at greater depths, smaller clasts supported by sphalerite and galena. Occasional finely laminated internal sediments, inclined bedding.
233-239'	M3 (lower Amco) - dark-grey, slightly argillaceous dolomitic clasts supported by coarse galena and fine colloform sphalerite.
239-323'	Watt Mountain Formation - collapse continues; large, angular fragments of Watt Mountain lithologies, predominantly grey, micritic dolostone. Clasts are supported by fine-grained light to very dark colloform sphalerite as above. Small amount of calcite veining and some native sulphur, very local. Gritty, loosely-consolidated dolostone (may be internal sediments or Watt Mountain Gritty member) at 250' this is nearly all replaced by sphalerite and some sucrosic galena.
315-323'	Rubble zone - loose, shaley, very dark greenish-black. Abundant rust. Lower portion shows some calcite cement, and internal sediments.
323-445'	Sulphur Point Formation - white to bluish-grey dolostone, coarsely -recrystallized and Presqu'ilized. Appears brecciated and veined by white calspar and dolspar. Short occasional intervals of loose, grainy, internal sediments. Very minor galena and sphalerite content.

383-398'	Muskeg Formation (J Facies/C Horizon) - J1/J3 intervals, dense, dolomitic interval locally brecciated, supported by sandy, internal sediments, loosely-consolidated and distinctly-bedded.
393-400'	Massive sulphides - fine colloform sphalerite, with coarse-grained galena infilling botryoids.
400-406'	Strongly Presqu'ilized dolostone - coarsely recrystallized; (may be Presqu'ilized Muskeg Formation or Presqu'ilized internal sediments).
406-445'	Presqu'ilized dolostone, blue-grey to white, grainy, internal sediment intervals occasionally. Below 420, calcite-flooded with weak SRF development. Blue-grey dolspar and calspar veining.
445-475'	Pine Point Formation - D1 Facies, light-grey to tan, fine dolarenite, fragmental, fossiliferous, moderately to weakly Presqu'ilized to 455. A few small intervals of internal sediments above 455 and large coarsely crystalline calcite veins.
475'	End of Hole.

N81-75

0-75'	Overburden
75-201'	Slave Point Formation
75-144'	O Facies - light to dark brown, slightly argillaceous limestone with wispy argillaceous partings, intraclastic beds and ripped up/flazer beds. Very fine, single, euhedral galena in pores.
117-118' 129-132'	P beds - similar to above, silty limestone with 20% oncolitic stromatoporoid fragments, brachiopod fragments. Fossils are replaced by white calspar. At 131 amphipora marker-bed, very dark carbonaceous limestone with about 15% calcite-replaced amphipora fragments.
144-180'	N Facies - dolostone, light-tan to dark-brown, carbonaceous/bituminous, micritic to variably-laminated. A few short intraclastic intervals and occasional calcite replacement blebs and along bedding planes. Native sulphur is frequently associated with calcite replacement.
180-187'	M2 (upper Amco) - dark-brown carbonaceous/bituminous dolostone, very churned-up texture (appears bioturbated).
187-197'	M1 (Amco shale) - marl, grey, mottled-character, also appears slightly bioturbated. Lower contact marked by calcite replaced brachiopods, still articulated.
197-201'	M3 (lower Amco) - grey to brown dolostone; stromatoporoid fragments, intraclastic/bioclastic, contains some oncolitic stromatoporoid fragments and thin-shelled brachiopods.

201-243'	Watt Mountain Formation - highly variable section of dolostone, calcareous dolostone and shaley dolostone. Textures vary from weakly-laminated, stylolitic, and sandy/silty loosely-consolidated intervals. Local intervals contain open-space filling and replacement by white calcite and native sulphur.
243-367'	Sulphur Point Formation.
243-260'	Rubble Zone - (erosional unconformity) green shale and clay horizon, with silty, argillaceous fracture-fill.
246-273'	Micritic dolostone - bioclastic, beige to grey with abundant disseminated bitumen.
273-283'	Presqu'ilized dolostone - small karst horizon, large calcite filled cavities, lined with bitumen and sparry calcite. Crackle-breccia zones cemented by white calcite. Small (<6") intervals of crumbly calcite with greenish, interstitial silt.
283-297'	Internal sediments/breccia - brown, sucrosic character (also Presqu'ilized) filling in between Sulphur Point clasts. Associated calspar veining prominent, some veins are lined with bitumen. Native sulphur ocasionally in calcite-filled veins. (At 295 rods dropped 3').
297-320'	Presqu'ilized dolostone, bioclastic wackestone/floatstone. Abundant fossil "ghosts" and fossil moldic vugs. Very light-coloured, grey to beige with dark-grey blotches locally due to bitumen and/or fine FeS_2. Prominent white calcite veining and very weak, local SRF development.
320-330'	Limestone -some bitumen impregnation and calcite veining but mostly beige micrite with about 5% amphipora.

330-336'	Presqu'ilized bioclastic floatstone - cream to beige with local blue-grey blotches.
334-381'	Karst interval.
334-355'	Presqu'ilized bioclastic floatstone - with intervals of internal sediments. Below 343 small SRF's are well-developed. Internal sediments become more continuous with depth and more granular.
355-365'	Dolostone - dark grey and white speckled granular, marcasite - impregnated internal sediments. Weakly Presqu'ilized.
365-381'	Dolostone - rhombic-crystalline, sucrosic, dolspar/calspar veined to 370. From 370-375 minor specks of sphalerite and galena and local vein-filling sulphides. From 378-381 laminated, grainstone with disseminated galena and sphalerite (ore grade).
381-391'	C Horizon (Muskeg Formation) - dense, dolarenite and micritic dolostone. Weakly Presqu'ilized with minor disseminated sphalerite and galena.
391-429'	Presqu'ilized dolostone, rhombic texture, some fossil ghosting and fossil moldic vugs preserved. Blue-grey discolouration after FeS_2. Minor disseminated galena and sphalerite.
429-467'	Dolostone, fine-grained, rhombic texture, prominent blue-grey colour after FeS_2. Calcite-flooded and veined with large calspar-filled fractures. Scattered occurrences of galena and spalerite.
467-500'	Pine Point formation.

467-475'	D1 Facies - light brown dolarenite, fossiliferous and locally fragmental. Minor galena and sphalerite in small fractures.
475-500'	E Facies - fine sandy, brown dolarenite, very rare fossil fragments.
500'	End of Hole.

N81-68A

0-44'	Overburden
44-222'	Slave Point Formation
44-72'	O Facies - light brown, argillaceous limestone, wavy argillaceous partings, nodular horizons, flazer texture and ripped-up bedding. Rare single, very small grains of galena.
72-245'	Collapse Breccia.
72-83'	Clasts of Slave Point lithologies in replaced and recrystallized section; upper 15' is 90% replaced by white and blue-grey dolspar, bitumen frequently fills small cavities. Indistinct colour zoning.
83-103'	Mostly N Facies (possibly some O Facies). P Bed at 90'. Weakly recrystallized and calcite replaced. Local intervals of Presqu'ilization and calspar/dolspar veining. At 96 angular clasts of dark-grey, finely-laminated very silty, dolostone - few small light coloured nodules, these look like internal sediments derived from N Facies dolostone. One clast shows very fine-grained, light beige sphalerite disseminated in recrystallized cement on the clast margin and very fine-grained 'skin' of galena and galena in very fine fractures within the clast.
103-136'	Continued N Facies - brecciated but does not appear very disordered. Occasional, finely bedded/silty internal sediments which appear to be derived from N Facies material.
136-143'	Massive sulphides - colloform sphalerite filled in by galena crystals. Minor interstitial porosity. Upper portion contains N Facies, brown mottled dolostone, bedding angles inclined and variable.

143-146'	Mostly sphalerite, uniform, medium brown (no banding or layering) open, "lace" texture. About 2% galena crystals in open spaces, well-formed cubes. Pyrrhotite well-formed cubes and tetrahedrons, tarnished to brilliant colours, crimson, green, blue, yellow. Very distinctive interval.
146-149'	Massive galena - quite granular, coarse textured, not particularly well-formed cubes except locally. Patches of light-brown, powder-fine sphalerite occur interstitially. Judging by apparent density of core this section is mostly galena. Minor white calcite in porosity.
149-180'	Mass of jumbled remnants of what appears to be N Facies (now mostly galena and sphalerite). Clasts of N show the sulphides replacing and infiltrating the original rock. This interval makes the hypothesis of replacement most plausible. Galena was the most abundant and likely the earliest to be deposited followed by sphalerite infilling. A "moth-eaten" vuggy porosity pervades and suggests leaching of fine fossil debris. Occasinally colloform sphalerite occurs in calspar/dolspar-filled veins along with sucrosic galena crystals.
180-182'	Massive, very fine-grained galena, extremely dense, looks like replaced mud. Calcite vein at top and bottom of interval.
182-187'	Brecciated, silty dolostone/siltstone, heavily replaced by galena and cemented by white calspar. A few small (0.5"), tan, micrite clasts preserved, floating in calcite cement. Around these clasts the calcite has a light-brown discolouration that looks like oil staining.
185-194'	Silty/sandy, finely-laminated, loosely-consolidated internal sediments.

194-200'	N Facies clasts with patches of sphalerite and galena mineralization.
200-209'	Internal sediments - clay, greenish-grey friable silt and small (<1.0") consolidated clasts of light-brown dolostone (N Facies).
209-222'	N Facies clasts, brown, internal sediments and greenish-grey clay. All are incompletely replaced by sphalerite and galena. A few of the galena crystals are 0.5-1 inch, across and are well-formed cubes. Sphalerite is fine-grained and light-tan, no colloform texture.
222-245'	M1 (Amco shale) - brecciated, grey, marl, crackled/collapsed, clasts cemented by well-developed colloform sphalerite which ranges from light-beige to dark-brown in colour. Coarse-grained sucrosic galena crystals. Shale clasts appear quite pristine and not replaced by sulphides.
245-380'	Watt Mountain Formation - stratigraphy of Watt Mountain lithologies more-or-less intact here, but karst/collapse continues with less disruption than in above section. Occasional intervals of finely-laminated, well-consolidated internal sediments.
245-300'	Watt Mountain Formation - brecciated and cemented by white calcite and associated colloform sphalerite and galena. Sphalerite is seen disseminating into clasts from adjacent fractures and replacing the dolostone. Some minor occurrences of native sulphur fill vugs in calcite veins. The abundance of white, vein calcite and native sulphur increases with depth to 320. Occasional dark-brown, euhedral sphalerite crystals in calcite.
320-335'	Internal sediments - sucrosic, loosely-consolidated grey to grey-green (salt and pepper character) a few Watt Mountain clasts recognized.

335-380'	Silty dolostone - severely-weathered, dark-grey through brown, locally colloform sphalerite and galena in fracture, other open-space fillings and in association with coarse calspar and dolspar.
380-425'	Sulphur Point Formation.
380-385'	Rubble zone - erosional unconformity, green clay and loose sucrosic dolostone with galena and sphalerite replacement, also finely laminated, well-consolidated grey/brown internal sediments at 384'.
390-425'	Presqu'ilized dolostone - coarsely recrystallized, thoroughly karsted, veined and replaced by white and blue-grey calspar and dolspar. Locally dark-brown, colloform sphalerite and galena are associated with the calcite. Native sulphur in cavities.
425-440'	Pine Point Formation - D1 Facies, sandy, light-brown dolarenite, fragmental and fossiliferous, cemented by white and blue-grey dolspar.
440'	End of Hole.

N81-84

0-80'	Overburden
80-176'	Slave Point Formation
80-99'	O Facies - light to medium-brown calcareous mudstone. Micritic to slightly silty. Occasional wispy, argillaceous partings and finely intraclastic intervals.
99-150'	N Facies - micritic limestone and fine crystalline dolostone, brown to grey. Textures vary from irregular blotchy and weakly-laminated to distinctly-laminated. From 120-125 sucrosic dolarenite horizon. Occasional calcite-filled fractures associated with native sulphur.
150-159'	M2 (upper Amco) - argillaceous limestone, mottled, churned-up character with about 5% small, thin-shelled brachiopods.
158-159'	M3-like interval - bulbous stromatoporoid fragments, digitate stromatoporoid fragments, coral (thamnopora?) and brachipods in a muddy dolostone matrix.
159-170'	M1 (Amco shale) - dark-green marl with a mottled burrowed character. Upper contact appears erosional, with a concentration of calcite replaced brachiopod shells.
170-176'	M3 (lower Amco) - floatstone with bulbous stromatoporoids, small brachiopods and intraclasts, dark, limey argillaceous matrix.
176-218'	Watt Mountain Formation - highly variable interval with minor sulphur in fractures and pores.
176-190'	Limestone - (minor dolostone) light grey to tan blotchy micrite.

190-195'	Gritty, intraclastic horizon, shaly matrix with limestone intraclasts.
195-200'	Micritic limestone, stylolitic, locally finely intraclastic.
200-215'	Mixed interval of tan micritic limestone and intraclastic shaley intervals. The micrite is grey to tan. Shale variety dark grey to green.
215-218'	Sucrosic dolostone with "moth-eaten" vuggy porosity.
218-406'	Sulphur Point Formation - micritic, bioclastic limestone, beige with grey intervals due to bitumen impregnation.
218-225'	Rubble zone - (erosional unconformity), Sulphur Point clasts with loosely-consolidated silt, clay and rubble of Watt Mountain origin.
318-301'	Bioclastic floatstone/wackestone, stylolitic micrite with up to 30% fossil material including very numerous gastropods, corals, stromatoporoids, brachiopods and amphipora. From 231-240 fossil debris has been abraded to less than 0.1".
225-231' 260-265'	Very abundant bitumen impregnation in pore spaces, gives dark-grey to brown discolouration.
263-276' 278-286'	Amphipora floatstone - very white micrite with about 10% amphipora. From 276-278 irregular, fine-laminations and calcite filling fenestral porosity, resembles fine algal laminations.
287-293'	Presqu'ilized dolostone - (incipient Presqu'ile) large irregular SRF's rimmed with brown "insoluble residue".
301-312'	White dolostone - possibly bioturbated?? resembles lime mud.
312-406'	Presqu'ilized dolostone.

312-335'	Karst channel - strongly altered and replaced interval of sparry calcite/dolomite and internal sediments. Cal/dolspar is white to very slightly blue. Internal sediments are coarse crystalline, medium-brown. Presqu'ilization effect showing in "insoluble residue" rims and "laminae" in internal sediments and with weak SRF's.
355-386'	C Horizon (Muskeg Formation) - alternating weakly-laminated, slightly calcite replaced, very dense, blue-grey dolostone and light brown dolarenite, sucrosic texture locally weakly laminated.
386-406'	Presqu'ilized dolostone - bioclastic floatstone/wackestone, grey to beige, coarse crystalline, locally blue-grey after fine-grained marcasite. Fossil moldic porosity and fossil "ghosts" are all that is preserved of the bioclastic character (<5% calspar/dolspar replacement).
406-450'	Pine Point Formation.
406-411	D3 Facies - dolostone, finely crystalline, dense, fragmental rock with abundant semi-rounded stromatoporoid fragments. Blue-grey colour due to very fine-grained disseminated sulphides.
406-430'	Dolostone - similar to above, fine-grained matrix with fossil fragments including stromatoporoids, brachiopods, possibly amphipora and small coral fragments. Variably Presqu'ilized, in places showing segregation of 'insoluble residues" and minor amounts of white calcite (<2%).
430-450'	E Facies - light-brown dolarenite, uniform, homogeneous interval.
450'	End of Hole.

N81-98

0-81'	Overburden
81-230'	Slave Point Formation
81-170'?	O Facies - light brown, slightly argillaceous limestone, wavy, anastamosing, argillaceous partings, intraclastic/nodular horizons. A few isolated galena crystals, very small.
88-96' 123-130'	P bed - micritic limestone with fine fossil debris, thin-shelled brachiopods, gastopods and fragments of oncolitic stromatoporoids. Locally nodular/rip-up horizons.
130-135'	Silty limestone - fine-grained, quite uniform, and featureless.
135-170'	O/N Facies - crackle-breccia, strongly replaced by white calcite. Blue-grey original limestone is preserved as clasts (1" to 12") in calcite cement. Calcite infilling occurs along bedding giving a "zebra-striped" character. Dissolution has occurred along bedding planes, giving a fenestral porosity. 160-170 galena occurs apparently in fractures (poor recovery makes this uncertain).
170-230'	Karst/collapse - collapsed interval of N Facies lithologies preserved as angular clasts up to 12 inches across, cemented by massive colloform sphalerite and galena as open space filling. Galena and sphalerite also occur disseminated in clasts. Sphalerite ranges in colour from very light-beige to black. Galena is generally quite fine-grained and intimately layered with colloforms of sphalerite, and occasionally as masses of skeletal galena. At 196 large, well-formed sphalerite botryoids are clearly cross-cut by calcite which contains a dark mineral (bitumen or sphalerite). From 210-230 massive

	colloform sphalerite intervals show very vuggy, ("lacey" or "moth-eaten") character.
230-245'	M2 (upper Amco) - clasts of dark-brown to grey dolostone cemented by massive galena/sphalerite and bituminous calcite.
245-253'	M1 (Amco shale) - grey, nodular, marl, few local stringers/lenses of galena. Rather unusual M1 character, relatively light colour, not visibly replaced or impregnated with iron sulphides as most ore-bearing cores show.
253-254'	Mass of euhedral galena crystals (0.25") in powder-fine matrix of yellow sphalerite. Lower contact is a coarse crystalline calcite vein.
254-340'	Watt Mountain Formation.
254-328'	Recognizable clasts of Watt Mountain lithologies, brecciated and cemented mostly by white calcite. Calcite in pores and in fractures, locally associated with very fine-grained, light-brown sphalerite and galena, minor amount of marcasite.
328-340'	Presqu'ilized dolostone, much more disordered breccia than above. Clasts of assorted Watt Mountain lithologies floating in calspar matrix, white with blue-grey margins on clasts. Some internal sediments. Portions of this interval are crumbly and have a weathered character which is associated with the erosional unconformity. Bitumen fills small vugs.
340-355'	Sulphur Point Formation.

340-395'	Presqu'ilized dolostone - karsted, overall blue-grey dolostone, veined and replaced by white calspar and white and blue-grey dolspar. Intervals of recrystallized internal sediments are frequent. Colloform sphalerite filling open spaces is mostly brown to black, but localy light-brown and yellow layers occur. Internal sediments become more prominent with depth as well as more granular and less well-consolidated. Appears that this is the base of the karst channel.
395-412'	Muskeg Formation (C horizon) - internal sediments, Presqu'ilized, argillaceous, J2/J3 horizons and dense, blue-grey J1 horizons, interbedded with intervals of brown, finely-bedded internal sediments.
402-403' 405-406'	Massive, coarse crystalline galena with colloform sphalerite infilling as well as some white cal/dolspar and occasional native sulphur.
412-455'	Sulphur Point Formation - totally Presqu'ilized and cal/dolspar replaced intervals of very silty, argillaceous loosely-consolidated internal sediments. No sulphides until 445', 1 foot interval of massive, colloform sphalerite and galena. Below this abundant disseminated and vug-filling sphalerite and galena.
445-490'	Pine Point Formation.
455-481'	D1 Facies - sandy, brown dolarenite, fine-grained, fragmental, very poorly recovered - chunky, ground core. Locally very fine FeS_2.
481-490'	E Facies - light-brown dolarenite. Very fine fossil fragments, possibly of rugose corals and stomatoporoids.
490'	End of Hole.

N81-99

0-71'	Overburden
71-257'	Slave Point Formation
71-110'	O Facies - light-brown, argillaceous limestone. Wispy, irregular bedding and intraclastic horizons. Locally very fine-grained galena and possibly marcasite in pores and very small fractures (rare).
81-86'	P bed - as above with oncolitic stromatoporoid fragments in light-brown limestone and very abundant thin-shelled brachiopods. A very few calcite-filled veins are seen but no brecciation.
110-119'	Bitumen-impregnated limestone, very poor recovery, badly broken and ground core. Preserved pieces indicate that the original rock was quite vuggy, some fenestral porosity and filled with bitumen and calcite.
119-124'	Poor recovery continues, galena is prominent here and appears to be filling open-spaces and fractures.
124-135'	The top of this interval may be the O/N contact. Grey to grey-brown limestone, strong intraclastic and churned-up character. By 126' sulphide minerals are filling small fractures, galena alone and galena with sphalerite (galena center with sphalerite margins) and sphalerite disseminating into rock adjacent to fracture. Calcite also filling pores and as rims to sulphide-filled fractures. At 130 massive colloform sphalerite with calcite-filled small vugs and fractures. Sphalerite masses are finely laminated and colours vary from yellow through very dark-brown.
134-135'	As above but very porous with vuggy, "lacey" character.

135-190'	Massive sulphides - no original rock can be identified. This interval consists of sphalerite and galena, very fine-grained mineralization with calcite filling any pores and openings along bedding. Textures include; interbedded, very fine-grained massive galena and massive light-brown sphalerite. These textures suggest sulphides have replaced the entire original rock, preserving original textures; colloform sphalerite and galena infilling cores of sphalerite botryoids. Sphalerite is highly varied in colour from very light-yellow to very dark-brown. Calcite varies in abundance from rare in the bedded textures to locally up to 1% in colloform zones. No where is there any sign of brecciation or calcite veining.
190-220'	Massive sulphides continue. Textural change to much finer-grained and calcite-flooded. Colour and grain size variation give a mottled character reminiscent of the bioturbated character of the M2 (upper Amco).
190-200'	Contains calcite-filled pore-spaces and numerous horizontal fractures. At 200 a decrease in core recovery suggests the top of the karst dissolution channel.
220-247'	Amco shale - breccia, massive FeS_2, fine granular texture and metallic-green colouration. 220-228 crackle-breccia cemented by white dolspar (2" to 12" clasts) cemented by white dolspar or filled in by very fine galena and sphalerite. Looks like sulphide replacement of mud. At 233 first occurrence of blue-grey dolspar.
247-249'	M3 (lower Amco) - clearly discernable oncolitic stromatoporoid fragments in an unevenly-coloured brown dolostone. Disseminated sulphides throughout and sulphide zoning follows oncolitic layering, calcite fills vugs and pores.

252-257'	Internal sediments - intraclastic/lithoclastic, finely bedded, variable bedding angles observed, some draped bedding around intraclasts. Light brown to light-grey beds interbedded with white dolospar and some minor calspar. Generally very dense and competent material. Minor amount of dolspar occurs filling fractures and associated with bitumen.
257-308'	Watt Mountain Formation - light-grey to tan dolostone, becomes fragmental at 262. From 262-267 few fractures and lithoclast margins are filled with sphalerite, minor galena and white calcite.
267-308'	Alternating short intervals of nodular/intraclastic fragments and finely-bedded dolostone, may be internal sediments. At 277 loosely-consolidated internal sediments are heavily impregnated with FeS_2 and some sphalerite and galena.
308-368'	Sulphur Point Formation - karsted, brecciated and Presqu'ilized interval. Overall colour is white to light blue-grey. Bioclastic origin suggested by fossil "ghosts". Breccia is cemented by white calcite and white and blue-grey dolospar. Below 315 interval becomes increasingly fragmental. Internal sediments (also fragmented) are finely bedded, blue-grey and Presqu'ilized. Sphalerite commonly fills small fractures and rims fragments. At 334-349, intervals of massive colloform sphalerite infilled by finely crystalline galena.
334-349'	Core recovery drops and section becomes increasingly less-consolidated. The rock appears to be argillaceous, internal sediments with sporadic occurrences of massive botryoidal sphalerite.
368-381'	C Horizon (Muskeg Formation) - interbedded, very dense dolarenite and dense micritic dolostone.

381-443'	Sulphur Point Formation - bioclastic dolostone, light-grey, calcite-flooded. Scattered, disseminated sphalerite. Below 415 fine grey FeS_2 impregnation and replacement by white dolspar.
443-475'	Pine Point Formation - D1 Facies , very fine-crystalline dolostone, crackle-breccia, light-brown to beige, locally fossiliferous with small rugose corals, stachyodes and stromatoporoids. About 1% calcite fracture-filling. Local fine-grained galena in fractures and rare native sulphur.
475'	End of Hole.

N81-76

0-83'	Overburden
83-201'	Slave Point Formation
83-144'	O Facies - light-brown to grey argillaceous limestone. Intervals of intraclasts, rip-up clasts, and wispy argillaceous partings.
92-95' 113-116' 125-130'	P beds - gritty, argillaceous limestone with stromatoporoid fragments and thin shelled brachiopod fragments. At 131 amphipora marker-horizon. Very dark-brown, bituminous limestone with 25% amphipora.
144-176'	N Facies - dolostone, cream colour, and dark-brown through grey. Bedding is horizontal and well defined.
154-160'	Dolostone, dark-brown, bituminous interval, well-laminated. "Moth-eaten" vuggy porosity suggests removal of evaporites. Some vugs filled by native sulphur.
176-187'	M2 (upper Amco) - dark-brown, argillaceous/bituminous dolostone, bioturbated, churned-up character. Only minor calcite in hairline fractures.
187-197'	M1 (Amco shale) - dark-grey to blue-grey dolomitic shale, competent.
197-201'	M3 (lower Amco) - dark-brown argillaceous/bituminous dolostone, fossil debris about 10% includes crinoid, brachiopod and stromatoporoid fragments.
201-243'	Watt Mountain Formation - highly variable section of calcareous dolostone and shaley dolostone. From 228 karsted with intervals of coarse-grained, sucrosic, loosely consolidated internal sediments.

243-434'	Sulphur Point Formation.
243-264'	Brecciated, cal/dolspar replaced, Presqu'ilized with prominent bitumen lining fractures and disseminated in sucrosic, Presqu'ilized internal sediements.
264-294'	Limestone, white to beige, bioclastic floatstone with patches of disseminated bitumen.
294-496'	Presqu'ilized dolostone.
294-350'	Severely Presqu'ilized, crystalline dolostone, cream to blue-grey, uneven colouring likely after fine-grained FeS_2. Locally fossil "ghosting" and fossil moldic vugs. Incipient SRF development to 300 ft. after this SRF's well-formed and close-packed.
350-380'	Karst/internal sediments. Sulphur Point dolostones as above with intervals of coarse loosely-consolidated to well-cemented, grey internal sediments. Cal/Dolspar veining prominent and some native sulphur occurs with calspar. Occasional occurrences of sphalerite, disseminated in internal sediments and as colloforms in calcite filled fractures.
380-382'	May be more internal sediments of Muskeg Formation (C Horizon) very sandy, clastic appearance, heavily replaced by dolspar and massive FeS_2 replacement.
382-392'	Muskeg Formation (C Horizon) variable dolarenite interval and dense blue-grey dolmicrite.
392-405'	Presqu'ilized bioclastic dolostone, beige to cream colour. Appears to be transitional from Sulphur Point to Muskeg Formations.

405-434'	Presqu'ilized rhombic dolostone. Light brown to grey, coarse, close-packed SRF sections are prominent.
434-500'	Pine Point Formation
434-496'	D1 Facies - tan, fine-grained dolarenite, fossiliferous, small fragments of stromatoporoids and possibly amphipora. Crackle-breccia cemented by white calcite.
434-456'	Calcite-flooded, rather corroded, weathered character. Minor traces of galena and sphalerite in pore spaces.
483-496'	Internal sediments, coarsely crystallized, brown, porous, locally faint bedding is inclined.
496-500'	E Facies - light-brown dolarenite, also porous, earthy character, calcite-flooded.
500'	End of Hole.

APPENDIX II

THIN SECTION DESCRIPTIONS

Thin Section Descriptions

R86454-56A (77.5') Slave Point Formation - O Facies: Calcareous mudstone with calcite veining. Distinctly intraclastic and pelletoidal. Clasts are often nodular. Calcite fills pore spaces and replaces fossil debris. Less than 0.5% of total is made up of opaque minerals, anhedral to euhedral crystals of marcasite and possibly some very fine-grained pyrite.

R86455-56A (97.5') Slave Point Formation - O Facies: Strong pelletoidal character, breccia, dark limestone clasts supported by carbonate. Clasts are nodular and/or intraclastic with less than 1% fossil debris (brachiopods). Calcite veins carry brecciated sphalerite grains which are anhedral and purple to colourless. Galena is associated with the sphalerite and is also brecciated.

R86457-56A (135') Sparry calcite: Galena cubes in calcite matrix with intergrowths of anhedral sphalerite. Galena locally brecciated. Small percentage of anhedral pyrite occurs within carbonate matrix only.

R86458-56A (145') Colloform sphalerite and galena: Open-space filling sphalerite is orange-yellow with stalactitic banding. Two generations of sphalerite: coarse crystals on exterior of botryoidal sphalerite aggregates. Galena may be replacing sphalerite. Minor veinlets of marcasite cross-cut sphalerite. Very small amount of sphalerite.

R86459-56A (155') Very similar to R86458: Galena cleavages are locally curved. Galena may be replacing sphalerite. Very minor amount of marcasite in veinlets.

R86460-56A (160') Predominantly calcite with sulphides: Sphalerite is yellow, mainly coarse-grained, euhedral, no botryoidal-forms here. Galena shows curved cleavages and may have been partially replaced by sphalerite. Very minor amount of marcasite. Lath-shaped carbonate crystals appear to be pseudomorphs of earlier euhedral, evaporite minerals.

R86461-56A (182') Intraclastic, calcareous mudstone: Galena is the most abundant sulphide mineral, anhedral to euhedral (octahedral), held in the mudstone matrix. Very minor amount of sphalerite. Minor amount of marcasite as crudely radiating crystal aggregates.

R86462-56A (222.5') Vein of sparry calcite containing sulphur and orange-yellow to dark reddish-brown sphalerite. Also minor amount of galena possibly replacing sphalerite. Dolostone groundmass contains minor amount of marcasite.

R86465-56A (362.5') Sphalerite, brecciated and overgrown by botryoidal sphalerite. Galena less abundant than sphalerite, may be replaced by sphalerite. Very minor marcasite. Paragenesis: sphalerite followed by calcite, galena, sphalerite, sulphur followed by botryoidal sphalerite which partly replaces original galena.

R86479-31A (315') Massive sparry calcite with reddish, octahedral sphalerite growing within galena. Very minor amount of marcasite.

R86480-31A (317') Sparry calcite and dolomites: large transparent euhedral sphalerite grains, colour-zoned: bright yellow to red with radiating texture. Galena is frequently skeletal, may be an empty shell or may be filled by sphalerite. Marcasite is very much more anisotropic than in Hole 56A and continues to appear hosted by calcite.

R86481-31A (322') Sparry calcite and dolomite with strongly-zoned euhedral sphalerite crystals and very minor amounts of galena. Marcasite is abundant and very strongly anisotropic. Sphalerite is in the form of radial aggregates and single euhedral crystals. Possibly sphalerite is replacing marcasite.

R86482-35 (267') Sparry calcite and dolomite with pale yellow to red sphalerite and minor amount of galena and marcasite.

R86483-35 (297') Sparry calcite and dolomite with a very large amount of primary marcasite. Marcasite is in the form of aggregates of bladed crystals, with polysynthetic twinning, very strongly anisotropic, brown to blue.

R86484-35 (312') Coarse-grained calcite and dolomite containing marcasite and pyrite, pale sphalerite and minor amount of galena. Galena has bent cleavages, is partly botryoidal in form, difficult to say whether galena is being replaced by sphalerite or vice versa. Marcasite is partly replaced by an oxide mineral.

R86485-35 (315') Sparry calcite and dolomite with large grains of galena containing sphalerite. Marcasite shows polysynthetic twinning, and radiating aggregates. Very few crystals of pyrite.

R86486-35 (337') Sparry calcite and dolomite with very abundant marcasite, well-twinned, and a few cubes of pyrite. Sphalerite is also contained in the carbonate groundmass, no visible galena.

R86487-35 (350') Sparry calcite and dolomite with abundant sphalerite and marcasite. Marcasite is later than sphalerite and forms aggregates of bladed crystals.

R86488-35 (372') Dolomite matrix hosting bladed marcasite, sphalerite and galena. Galena is very minor and fine grained, appears to be replacing marcasite.

R86489-3 (130') Alternating botryoids of galena and marcasite, masses of botryoidal sphalerite and interstitital calcite. Coarse-grained, euhedral sphalerite forms a 'crust' of botryoidal sphalerite. Chalcopyrite or some iron sulphide exsolving from sphalerite. Skeletal grains of galena form cores of stalactitic sphalerite. Botryoidal galena external to some stalactities is associated with marcasite. Individual dendritic 'arms' of these skeletal crystals cross-cut banding of botryoidal sphalerite. Appears that this may have been a 'feathery' mass of skeletal galena followed by sphalerite. Carbonate pseudomorphs of sulphate laths are also prominent.

R86490-3 (137') Galena shows prominent curved cleavages. Marcasite is rhombic in cross-section with simple twinning. This slide is almost entirely sulphides: botryoidal sphalerite, coarse-grained galena, marcasite, and pyrite. Paragenesis: galena - brecciation - botryoidal sphalerite - marcasite. 'Cloudy' porosity associated with the FeS_2 suggests an inversion of marcasite to pyrite.

R86491-3 (147') Banded sulphides, banded yellow/orange sphalerite and galena. Paragenesis: galena - sphalerite - marcasite - calcite. Calcite infills spaces between stalactities of sphalerite and galena. Carbonate also as pseudomorphs after evaporitive sulphate minerals.

R86492-3 (160') Similar to R86461. Abundant sphalerite, coarsely crystalline exterior of botryoidal sphalerite. Galena, marcasite and calcite fill spaces between botryoids. Botryoidal galena being replaced by marcasite. Pyrite may be replacing marcasite. Lath-shaped carbonate pseudomorphs of evaporative sulphate minerals occur within sphalerite botryoids.

R86493-3 (165') Massive sulphide about 50% galena and 50% sphalerite. Sphalerite is botryoidal and some appears to contain exsolved chalcopyrite. Galena is in part coarse-grained and interstititai to sphalerite botryoidals. The remainder occurs as botryoidal layers in stalactities. In places dendritic galena cuts stalactities. Very small amount of euhedral marcasite.

R86494-3 (175') Similar to R86493. Paragenesis: botryoidal sphalerite - galena - euhedral sphalerite - calcite and galena. Galena is coarse-grained and appears brecciated, may be in part replaced by sphalerite. Calcite hosts abundant marcasite, some of which is replaced by pyrite. Botryoidal sphalerite locally has cores of dendritic galena.

R86495-3 (187') Similar to R86493 and R86494, overall brecciation of botryoidal crusts. Breccia is infilled with coarse-grained galena and sparry calcite. Minor dendritic galena and marcasite.

R86496-3 (200') Considerably more calcite than in R86494 and R86495, but otherwise similar. Brecciated stalactities invaded by calcite. Paragenesis: galena - sphalerite (replacing galena) - brecciation - calcite.

R86497-3 (215') Dolomite with sparry calcite veins. Minor amount of sphalerite and less abundant galena, trace pyrite.

R86498-3 (222') Dolomite with veins of sparry calcite. Minor marcasite and brecciated sphalerite and galena.

R86499-3 (235') Botryoidal sphalerite overgrown by coarse-grained, euhedral sphalerite and coarsely crystalline calcite. Galena is dendritic and forms 'cores' to botryoidal sphalerite. Marcasite has locally reverted to pyrite.

R86500-3 (247') Amco shale clasts replaced by pyrite (after marcasite). Brecciated and cut by veins of earlier botryoidal, yellow to brown sphalerite and later coarse-grained euhedral sphalerite and galena.

R86501-3 (252') Coarse-grained, brecciated rock with extremely dark brown sphalerite surrounded by lighter coloured sphalerite. Coarse-grained sphalerite is intergrown with galena and may be in part replaced galena. Marcasite is partly reverted to pyrite.

R86502-3 (262') Fine, sucrosic dolomite, contains disseminated sphalerite. Sphalerite is coloured yellow, colourless and purple. Abundant FeS_2, local domains of marcasite are preserved but most have reverted to pyrite.

R86503-3 (285') Coarsely crystalline calspar and dolspar, containing an assemblage of galena, sphalerite and minor marcasite (locally reverted to pyrite). Galena is euhedral with curved cleavages. Very tiny, late veins of calcite, containing marcasite, cross-cut everything.

R86505-3 (322') Assemblage of coarse-grained dolospar, coarse-grained yellow and colourless sphalerite and coarse-grained galena. All brecciated. Marcasite is associated with galena. Pyrite is later and occurs in calcite.

R86506-2 (367') Mass of sparry calcite in vein system, with small amount of sphalerite and galena.

R86507-3 (367') Paragenesis: sphalerite - galena - calcite - marcasite. Sphalerite is euhedral. Sphalerite exhibits a vivid purple core, with colourless intermediate zone and yellow/brown outer zones.

R86508-3 (205') Honeycombs of botryoidal forms, brecciated and cemented by coarse-grained sphalerite and galena. Some botryoids of sphalerite have cores of dendritic galena. Minor but obvious, euhedral, primary marcasite and galena may have been replaced by sphalerite. Paragenesis: dendritic galena - botryoidal sphalerite - galena (partly replaced by sphalerite).

R861449-41 (125') Collapse breccia zone, masive sulphide replacement of Slave Point Formation (O Facies). Carbonate pseudomorphs after sulphate laths. Beautiful, purple sphalerite in cores of euhedral crystals. Abundant sphalerite and calcite, minor late-stage marcasite and a trace of galena.

R861450-41 (130') Collapse breccia zone, sulphide-replaced (Slave Point Formation). Strongly-zoned euhedral sphalerite, brecciated with black cores, yellow midsection and colourless rims. Minor amount of carbonate pseudomorphs after evaporitic sulphates. Minor botryoidal galena and occasional botryoidal sphalerite, trace of marcasite.

R861451-41 (132.5') Same as R861455. Brecciated, zoned sphalerite with minor amount of marcasite and late-stage sparry calcite.

R861452-41 (147') Same as R861455. Very minor amount of carbonate pseudomorphs after evaporitis sulphates. Possible replacement of marcasite by pyrite.

R861453-41 (160') Botryoidal sphalerite with interstices filled with sparry calcite. Minor carbonate pseudomorphs after sulphate laths. Galena may be partly replaced by sphalerite. Minor carbonate pseudomorphs filled with sparry carbonate. Minor carbonate pseudomorphs after sulphate laths. Galena may be partly replaced by sphalerite. Minor marcasite (later stage), sphalerite shows small patches of Fe or Cu sulphides exsolving and being replaced by pyrite.

R861454-41 (170') Identical to R861455.

R861455-41 (175') Main component sphalerite, crustiform sphalerite, partly botryoidal, broken and cemented by sparry calcite. Galena shows deformed cleavage, dendritic cores in botryoidal sphalerite and botryoidal galena. Very coarse-grained, cubic galena associated with calcite.

R861456-41 (187') Amco shale breccia. Very fine aggregate of botryoidal sphalerite, locally dendritic galena forms cores. Exceptionally rich in marcasite. Marcasite is replaced by sphalerite and galena. Yellowish, speckled laths of finely divided pyrite are associated with sphalerite and galena.

R861457-41 (197') Amco shale breccia. Possibly a brachiopod replaced by sphalerite. Euhedral sphalerite, dark cores, lighter colours toward exterior. Interstitial spaces filled by calcite associated with minor marcasite. No visible galena.

R861458-41 (202') Botryoidal sphalerite with cores of dendritic galena. Botryoidal sphalerite is coated by euhedral, brown sphalerite and an external rim of fine pale coloured sphalerite. Carbonate pseudomorphs after sulphate laths as well as a white, mica-like mineral with very low 2V (other places uniaxial) (anhydrite??). Calcopyrite? exsolving from sphalerite, and marcasite (possibly pyrite) in late stage veinlets. Paragenesis: galena - sphalerite - anhydrite?? - removal of anhydrite and replacement by carbonate?

R861459-41 (207') Aggregate of botryoidal sphalerite, carbonate pseudomorphs of sulphate laths, minor galena and late stage marcasite. Sphalerite shows light exteriors and dark cores, galena is dendritic and forms cores of botryoidal sphalerite, sparry calcite occcurs interstitially.

R861460-41 (255') Amco shale breccia, totally obliterated by FeS_2. Marcasite veins carry sphalerite, appears that sphalerite and galena are replacing marcasite. Paragenesis: early marcasite - sphalerite and galena - sparry calcite.

R861461-41 (267') A mass of botryoidal sphalerite and carbonate pseudomorphs after sulphate laths. Sphalerite botryoids are zoned with dark brown cores and yellow to colourless exteriors. Dendritic galena forms cores to many sphalerite botryoids. Late stage marcasite and pyrite are minor constituents. A sphalerite botryoid possibly contains exsolved Cu or Fe sulphides.

R861462-41 (290') Sparry carbonate containing brown euhedral sphalerite. Intergrowth of carbonate and sphalerite laths (sulphate replacement?). A very small amount of late stage purple sphalerite and minor galena, minor marcasite and trace pyrite.

R861263-41 (325') Assemblage of sparry calcite and very coarse-grained sphalerite and minor amount of platy marcasite, partly replaced by pyrite.

R861464-41 (330') Sparry calcite and dolomite with coarse-grained yellow to clear sphalerite and minor purple sphalerite. Associated with the carbonates are pyrite, minor galena, marcasite and trace pyrite.

R865154-36 (127') Dolostone

R865155-36 (137') Slave Point Formation, N Facies: Fine, micritic dolostone with patchy sphalerite and veinlets of galena, coarse-grained, yellow sphalerite, and minor sparry carbonate. Paragenesis: sphalerite - carbonate and galena. Also traces of marcasite and possibly some pyrite.

R865156-36 (145') Sparry calcite with a peculiar "pseudomorph" effect. This unusual carbonate texture has very dark relict textures, semicircular to horseshoe-shaped. Locally these are rimmed by sphalerite. Fe sulphides have a distinct, acicular habit.

R865157-36 (147') Sparry calcite matrix with coarse-grained sphalerite, partly botryoidal texture, red, yellow, orange. Infilling of coarse-grained calcite and galena. Carbonate pseudomorphs after sulphates. Minor FeS_2, very fine-grained acicular form.

R865158-36 (150') Coarse-grained sphalerite, botryoidal sphalerite and galena. Abundant carbonate pseudomorphs after anhydrite. Distince lack of FeS_2.

R865159-36 (155') Coarse-grained calcite with veinlets of sulphur. Carbonate pseudomorphs after sulphate laths. Patchy, botryoidal sphalerite growing in calcite. Coarse-grained galena with slightly bent cleavages. Minor marcasite.

R865160-36 (157') Fine micritic dolostone with patchy sphalerite and galena, also minor marcasite.

R865161-36 (162') Botryoidal sphalerite with associated late-stage, sparry calcite, galena, minor marcasite. Galena cleavages slightly curved.

R865162-36 (165') Contact of fine micritic dolostone with patchy sphalerite and a vein with coarse-grained calcite and botryoidal sphalerite with coarsely crystalline sphalerite rims, minor galena and FeS_2 (marcasite and trace pyrite).

R865163-36 (167') Sparry calcite, replacement texture similar to R865156. Botryoidal sphalerite, orange-yellow. Minor galena and marcasite.

R865164-36 (170') Similar to 865158 with notable lack of FeS_2.

R8615165-36 (175') Botryoidal sphalerite with associated late-stage, sparry calcite, galena, minor marcasite. Galena cleavages slightly curved.

R865166-36 (182.5') Predominantly Fe-sulphides, mostly marcasite with some pyrite, with brecciated sphalerite botryoids and interbotryoidal galena. Late-stage sparry calcite cement.

R865167-36 (185') Mainly colliform sphalerite, pale yellow to dark brown, locally brecciated with interbotryoidal galena and sparry calcite.

R865168-36 (190') Similar to R865167, with darker sphalerite and increased amount of galena.

R865169-36 (197.5') Dense, fine-grained network of finely botryoidal sphalerite and galena. Few, small, late-stage fractures filled with calcite.

R865170-36 (207') Sulphidized evaporite horizon, layered, replaced sulphate. Abundant sphalerite, colourless to dark brown, and abundant galena forms a dendritic network.

R865171-36 (210') Mass of fine, botryoidal sphalerite, yellow to orange in colour. Also cream coloured, chalky-textured sphalerite. Dendritic and botryoidal galena and late-stage marcasite.

R865172-36 (215') Botryoidal, brown and orange sphalerite and later-stage colourless sphalerite and dendritic galena. Also cream-coloured, chalky-textured sphalerite. Dendritic and botryoidal galena and late stage marcasite.

R65173-36 (220') Botryoidal sphalerite with cores of "feathery" dendritic galena. Veins of later calcite and minor marcasite, partly replaced by pyrite.

R865174-36 (225') Intergrowth of coarse-grained calcite, botryoidal sphalerite associated with minor amount of dendritic galena and minor marcasite.

R865175-36 (230') Botryoidal sphalerite with dendritic galena and minor pyrite. Galena appears to be replacing pyrite locally.

R865176-36 (235') Breccia: fine-grained, sucrosic dolostone clast with late-stage calcite cement. The clasts contain abundant galena and sphalerite. Calcite cement contains sphalerite, galena and very fine-grained marcasite.

R865177-36 (240') Botryoidal orange and red sphalerite. Later sphalerite is colourless to yellow. Sparry calcite veins with coarse-grained sphalerite and galena.

R865178-36 (257') Botryoidal sphalerite, yellow, orange with colourless, crystalline sphalerite on the outside. Minor amount of marcasite in veinlets and minor galena.

R865179-36 (270') Brecciated internal sediments, laminated, granular clasts are grey to white in colour. Clasts are cemented by botryoidal sphalerite with sparry carbonate. Local purple coloured sphalerite.

R865180-36 (277') Botryoidal sphalerite in sparry calcite with minor galena. Sphalerite is orange, yellow, colourless. Minor amount of the purple variety of spalerite.

R865181-36 (282') Very coarse-grained, rhombic dolomite. Small sphalerite crystals growing in dolomite. Minor galena and marcasite, small vein of botryoidal sphalerite and coarse-grained galena.

R865182-36 (290') Coarse-grained calcite with abundant sphalerite and brecciated fragments of finer dolostone. Abundant sphalerite, galena, marcasite. The marcasite is in the dolostone clasts.

R865183-36 (295') Very fine-grained dolostone with disseminated sphalerite and marcasite. Clasts cut by coarse veins of yellow, orange sphalerite.

R865184-36 (300') Sparry dolomite. Coarse-grained, brecciated sphalerite (orange and colourless). Late calcite infilling is much more transparent than early dolomite. Very minor, late-stage galena and some marcasite.

R865185-36 (305') Coarse-grained, rhombic dolomite, coarse-grained sphalerite, highly abundant marcasite, well-twinned. Minor late-stage galena in cross-cutting veinlets.

R865186-36 (307') Sparry carbonate with later cross-cutting veinlets of clear carbonate. Coarse-grained sphalerite (dark red, orange and colourless zones), brecciated. Quite abundant marcasite, partly replaced by pyrite. Very minor galena.

R865187-36 (317') Coarse-grained, sparry dolomite. Very coarsely crystalline sphalerite, some zones (orange, yellow, colourless). Abundant twinned marcasite. No visible galena.

R865188-36 (327) Coarse-grained sparry dolomite with coarse-grained, orange-yellow sphalerite. Patchy sphalerite, abundant pyrite, minor galena. Pyrite appears to be replacing marcasite. Galena is very late-stage and locally dendritic.

R865189-36 (335') Association of sparry dolomite and small, scattered sphalerite crystals growing in dolomite cut by later more transparent calcite. Sphalerite colours range from red through orange and colourless. Minor skeletal galena in botryoidal sector. Trace marcasite in dolomite.

R865190-36 (340') Coarsely-banded aggregate of dolomite, galena and botryoidal sphalerite. Skeletal galena forms framework for botryoidal sphalerite. Very minor Fe-sulphides.

R865191-36 (345') Strongly botryoidal sphalerite, locally brecciated and infilled with very transparent sparry calcite. Botryoidal sphalerite is orange through yellow and colourless with cores of skeletal galena. Late-stage marcasite veinlets.

R865192-36 (390') Aggregate of botryoidal sphalerite with infilling of coarse-grained sphalerite (orange, yellow and colourless). Cores of some botryoidal forms are filled with abundant galena (some is skeletal). Minor late-stage marcasite.

R865193-36 (392') Highly brecciated, sparry dolomite and sphalerite. Very minor marcasite, no galena.

R865194-13 (238') Dolostone riddled with very attractive asciular and cubic Fe-sulphides (pyrite). Minor sphalerite.

R865195-13 (245') Sparry dolomite with occasional patches of coarse-grained orange to red sphalerite. Very abundant FeS_2 as marcasite, possibly partly replaced by pyrite.

R865196-13 (280') Coarse-grained dolomite with acicular iron sulphides (pyrite).

R865197-13 (352') Sparry dolomite with very coarse-grained, botryoidal sphalerite, purple, yellow and colourless patches.

R865198-13 (357.5') Similar to R865197.

R865199-13 (360') Coarse-grained aggregate of sparry dolomite, coarsely crystalline yellow and colourless sphalerite, partly brecciated. Very minor, coarse-grained galena. Fine-grained FeS_2 apears to be marcasite.

R865200-13 (370') Sparry calcite containing brecciated, coarse-grained sphalerite (yellow and colourless). Later veins of very clear, sparry calcite contain abundant marcasite. Traces of galena and sphalerite.

R865201-13 (337') Sparry calcite with twinned marcasite and minor trace of sphalerite.

R865202-1 (352') Sparry calcite and marcasite as in R865201.

R865203-1 (362') Coarsely-banded aggregate of sparry calcite with very coarse crystals of purple, orange and colorless sphalerite. Purple sphalerite shows sector twinning and zonation. Minor amount of marcasite.

R865204-1 (372') Coarse-grained sparry calcite with large crystals of yellow, colourless and purple sphalerite and marcasite.

R865205-50 (370') Sparry carbonate with large crystals of sphalerite, in part broken, (colourless, yellow and orange). Minor galena, marcasite is reverting to pyrite.

R865206-50 (380') Sparry calcite with very minor sphalerite and galena partly replacing surrounding marcasite.

R865207-50 (417') Sparry calcite with a minor amount of sphalerite and even lesser amounts of marcasite and galena.

R865208-55 (165') Within karsted interval, M2 (upper Amco). Banded sucrosic dolomite with cloudy yellow rhombs of calcite. Sporadic sphalerite (orange-yellow) and abundant pyrite and very fine-grained galena.

R865209-55 (170') Within karsted interval, M2 (upper Amco). Massive orange, yellow, and clear botryoidal sphalerite with cores of galena. Later vug-fillings of clear calcite.

R865210-55 (177') Within karst interval, M2 (upper Amco). Sucrosic dolomite (like R865208). Patchy development of brown and yellow sphalerite. Sphalerite shows darker cores and relatively light rims. Minor marcasite and disseminated galena. It appears that the sulphides have partially replaced the dolomite. Later vein of calcite present.

R865211-55 (185') Within karsted interval, M1 (Amco shale) massive marcasite replacement of M1 fragments. Coarse-grained sphalerite around fragments, colour-zoned, red, orange, colourless. Also minor galena and late, clear, sparry calcite.

R865212-55 (195') Coarse, massive, botryoidal galena with a coating of botryoidal sphalerite (orange, yellow). Vugs are filled by sparry calcite.

R865213-55 (202') Botryoidal galena, sphalerite and late-stage calcite. The sphalerite is red, yellow, orange and colourless. Very minor amount of late-stage marcasite.

R865214-55 (205') Similar to R865213. Paragenesis galena - sphalerite - brecciation.

R865215-55 (220') Identical to R865214.

R865216-55 (225') "Lacey", open-textured network of early galena followed by sphalerite, calcite and finally marcasite. Sphalerite forms are weakly developed botryoids.

R865217-55 (230') Similar to R865216. Sphalerite occurs here only as yellow and clear variety. "Feathery", dendritic galena habit.

R865218-55 (270') Karsted interval, Watt Mountain Formation. Coarse-grained galena on exterior of botryoidal sphalerite. Very coarse-grained colourless and yellow sphalerite, well zoned. Trace marcasite.

R865219-55 (295') Brecciated sphalerite shows colour zoning from interior to exterior: red, yellow, colourless. Breccia is cemented by clear calcite with a trace of galena.

R865220-55 (300') Brecciated calcarenite (cut by large calcite veins). Matrix contains a grey mineral (likely galena) replacing marcasite. Disseminated sphalerite.

R865221-55 (315') Massive galena network with interstitial sphalerite and sparry calcite.

R865222-55 (325') Brecciated botryoidal sphalerite with some galena. The early sphalerite is red-yellow zoned, coarsely crystalline followed by clear sparry calcite with native sulphur.

R865223-55 (335') Fragments of coarse-grained, rhombic dolomite surrounded by zoned, botryoidal sphalerite; dark orange, clear. Last stage is sparry calcite and galena in voids. Minor marcasite.

R865224-55 (340') Sparry calcite with good fluid inclusions. Definite carbonate pseudomorphs after euhedral bladed sulphate minerals.

R865225-55 (345') Carbonate pseudomorphs after evaporite minerals. Coarse-grained sphalerite, colours range from yellow to colourless. Sparry dolomite and later calcite disrupting original sulphide textures. Galena pseudomorphs of evaporites also.

R865226-69 (260') Coarse-grained sphalerite and sparry calcite. Minor galena and trace marcasite.

R865227-69 (270') Dense, 'chalky', botryoidal sphalerite surrounding dendritic galena. Vugs filled by sparry calcite and coarse-grained, colourless sphalerite. Trace marcasite.

R865228-69 (272') Dolostone with disseminated galena and sphalerite. Later vein of sparry calcite with galena.

R865229-69 (392') Masses of botryoidal sphalerite, coloured orange, red, colourless. Interbotryoidal spaces filled by colourless, coarsely crystalline sphalerite. Last stage is sparry calcite with some galena and native sulphur. No FeS_2 phase.

R865230-69 (395') Same as R865229. More abundant native sulphur.

R865231-69 (400') Sparry calcite with minor marcasite.

R865232-69 (402') Identical to R865231.

R865233-68A (145') Karst interval, Slave Point Formation. (N Facies). Coarse, botryoidal mass of yellow-colourless sphalerite. Many have cores of dendritic galena. Minor late-stage calcite.

R865234-68A (152') Paragenesis: coarse-grained galena - coarse-grained colourless and yellow sphalerite - sparry calcite. No FeS_2 phase seen.

R855235-68A (169') Excellent carbonate pseudomorphs after evaporite minerals. Very similar to R865234 but sphalerite preceded galena and carbonate.

R865236-68A (170') Massive sulphides comprised of coarse botryoidal sphalerite, coarse-grained galena in spaces and minor amount of carbonate pseudomorphs after anhydrite. No visible FeS_2.

R865237-68A (190') Finely-laminated dolostone with patchy replacement by sphalerite and galena. Also minor marcasite.

R865238-68A (210') Fine network of yellow botryoidal sphalerite and yellow calcite. Lath-shaped carbonate pseudomorphs after sulphate minerals. Also galena, euhedral sphalerite and a minor amount of marcasite.

R865239-68A (237') Paragenesis: crustiform development of sphalerite - finely banded orange, yellow, colourless, coarsely crystalline sphalerite - Coarsely crystalline galena and sphalerite in association with sparry calcite and sulphur. Minor amount of marcasite in early sphalerite.

R865240-68A (260') Coarse-grained dolomite cut by calcite vein. Vein may have had original anhydrite crystals which are now replaced by carbonate. The original acicular habit is well preserved in the carbonate. Very minor marcasite.

R865241-68A (279') Zoned yellow, colourless sphalerite. Open spaces filled by calcite with coarse-grained galena, minor marcasite (and possibly pyrite). All brecciated.

R865242-68A (285') Masses of coarsely botryoidal sphalerite. Acicular sphalerite pseudomorphs after evaporitic sulphate minerals. Later, coarsely crystalline galena, sphalerite and clear calcite.

R865243-68A (287') Brecciated. Well-preserved pseudomorphs after evaporitic sulphate minerals. Paragenesis: coarsely crystalline, zoned sphalerite, galena, minor pyrite - late stage calcite and native sulphur.

R865244-68A (312') Dolostone matrix, abundant botryoidal sphalerite and zoned euhedral sphalerite. Late-stage colourless calcite and minor marcasite. No visible galena.

R865245-68A (340') Sparry dolomite, some brecciation. Minor sphalerite, abundant pyrite and marcasite.

R865246-68A (342') Sparry dolomite, some brecciated. Minor sphalerite, abundant pyrite and minor marcasite.

R865247-68A (335') Coarsely botryoidal sphalerite preceded, botryoidal galena and minor marcasite.